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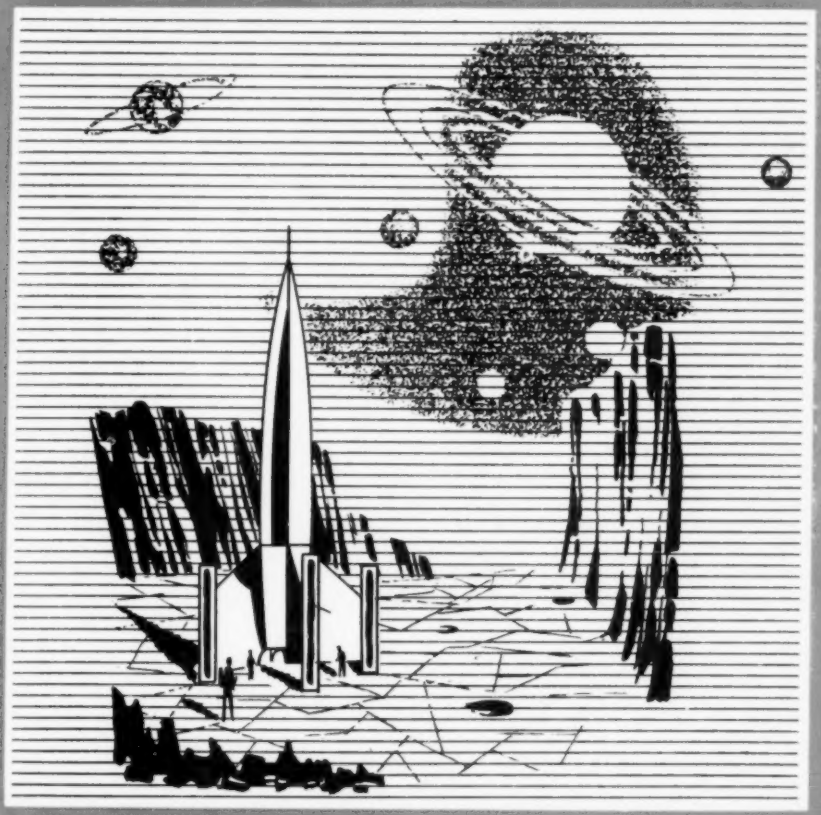
MATERIALS FOR MISSILES AND SPACE VEHICLES

(See page 211)



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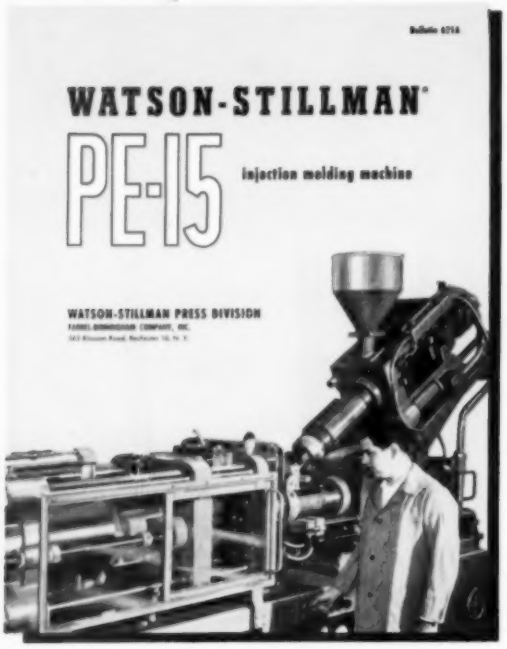

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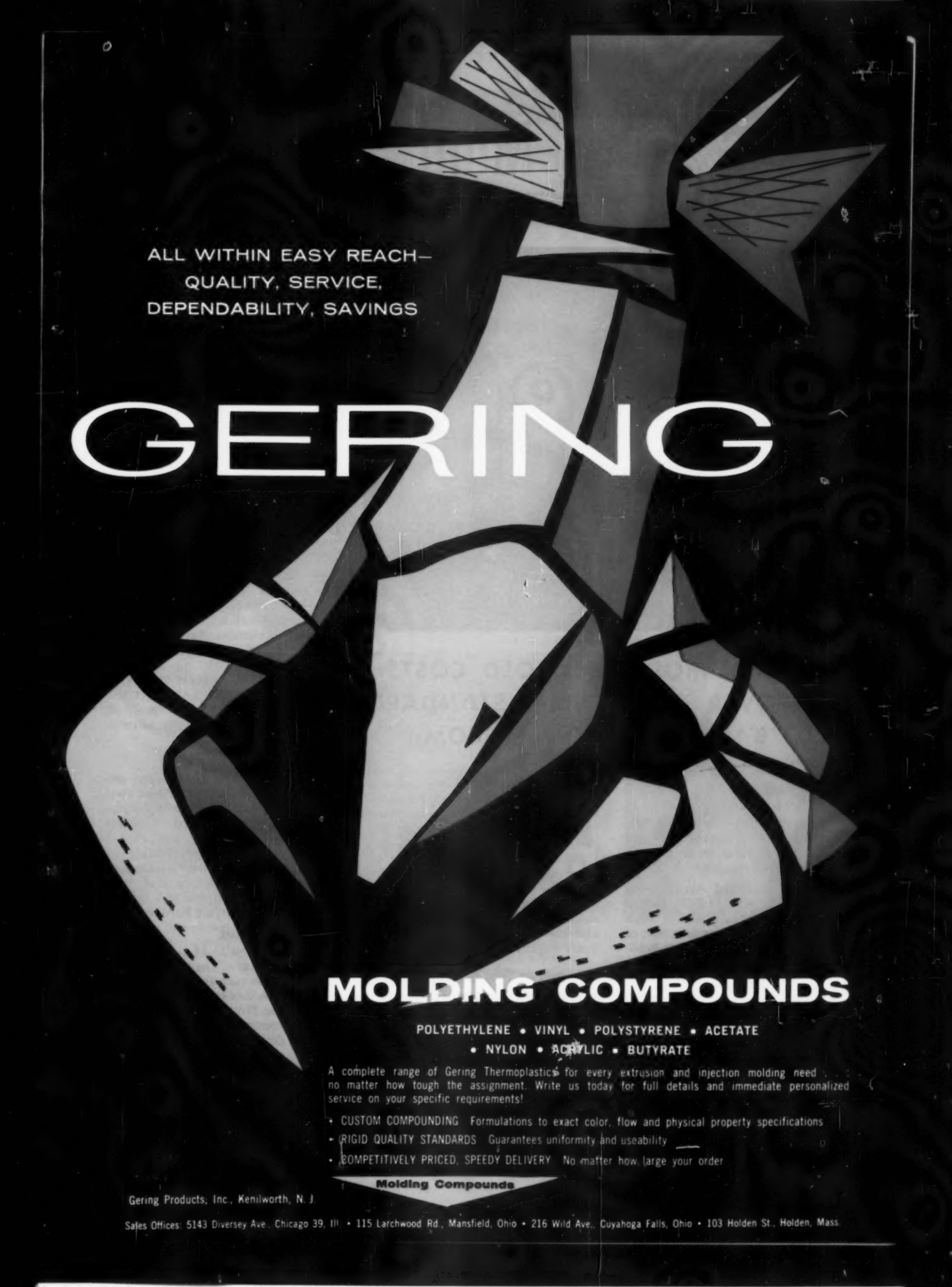
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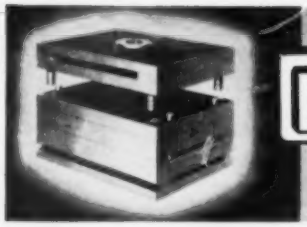

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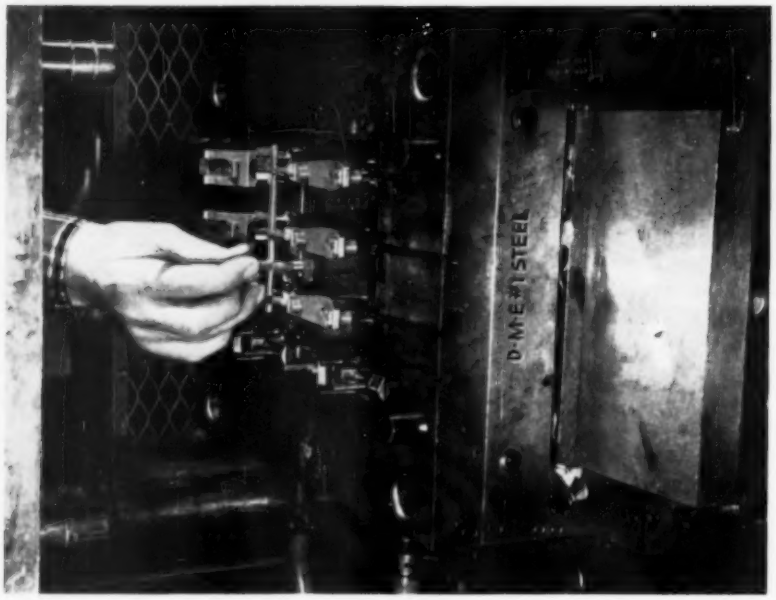

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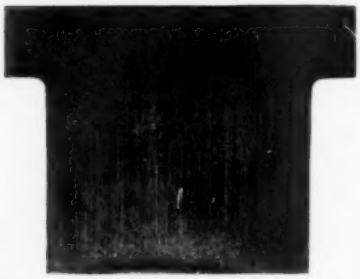
Comparison Tests Prove Advantages of D-M-E Ejector Pins



This cross-sectional photo-micrograph of the hot-forged head on a D-M-E Standard Ejector Pin reveals superior grain flow.

Plastic mold or die cast die ejector pins amount to a fraction of total mold cost. But ejector pins affect mold performance more than any other single element. Recognizing the importance of ejector pin performance, D-M-E carries on continual research and development to provide the finest ejector pins to meet the combination of grueling thermal and mechanical stresses ejector pins must withstand.

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...for rigidity, toughness, gloss and molding accuracy!

Toy manufacturers everywhere are beginning to realize the many advantages of switching to high-quality MARLEX linear polyethylene. Toys made of MARLEX have integral color that lasts and lasts—even after years of abuse. Children are protected against irritations because MARLEX is nonallergenic. Toys of MARLEX are easy to keep clean. They can be wiped with a sponge, washed in dishwashers, or even sterilized in boiling water. Toys made of MARLEX are tough, attractive and durable.

No other material serves so well and so economically in so many different applications. How can MARLEX serve you?

*MARLEX is a trademark for Phillips family of olefin polymers.

Child Guidance Toys picked MARLEX because of its excellent rigidity, toughness, gloss and molding accuracy. Their new Spinning Fan, Steam Iron and Mechanics Bench are excellent examples of colorful, durable, intricately molded toys that can be profitably made with MARLEX resin. The fan, for example, features self-lubricating MARLEX bevel gears.

This toy sports car and fire truck have numerous parts made of MARLEX...the tough, stiff, unbreakable roof, grille and bumper units, the fire ladder, and the self-lubricating cam mechanism. Trimold, Inc., Buffalo, N. Y., who molds these items for Fisher-Price Toys, says, "Color won't bleed into MARLEX from adjacent painted wood parts because MARLEX is impermeable."

Fun for young and old... the "Jeri Wheel" is molded by Arrow Plastic Molders of Inglewood, Calif. for the Original Jeri Wheel Co. This modern version of an old standby has removable metal weights for changing rolling action. Because it's made of MARLEX, the "Jeri Wheel" won't mar floors. MARLEX is unbreakable . . . nonallergenic . . . safe for children.

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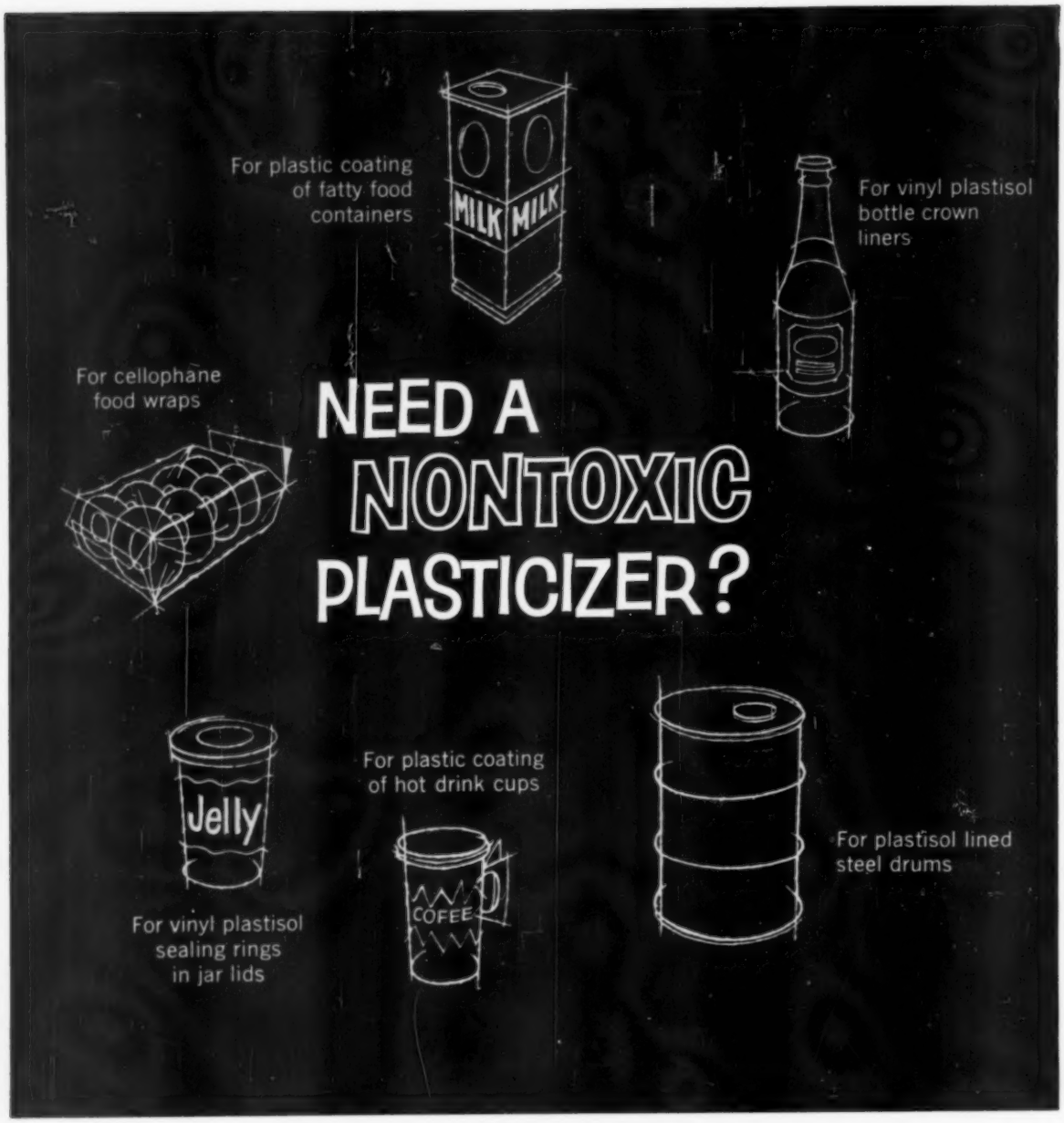
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Society of Plastics Engineers Journal

65 Prospect Street, Stamford, Connecticut

VOL. 15, NO. 3, MARCH 1959

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● The SPE Journal is Published at 440 Post Road, Orange, Conn. Address changes, undeliverable copies and orders for subscriptions should be sent to 65 Prospect St., Stamford, Conn.

● Entered as second-class matter at the Post Office at Orange, Connecticut. Accepted at special postal rate provided in paragraph (d-2), Sec. 34.40, P.L. and R., of 1918.

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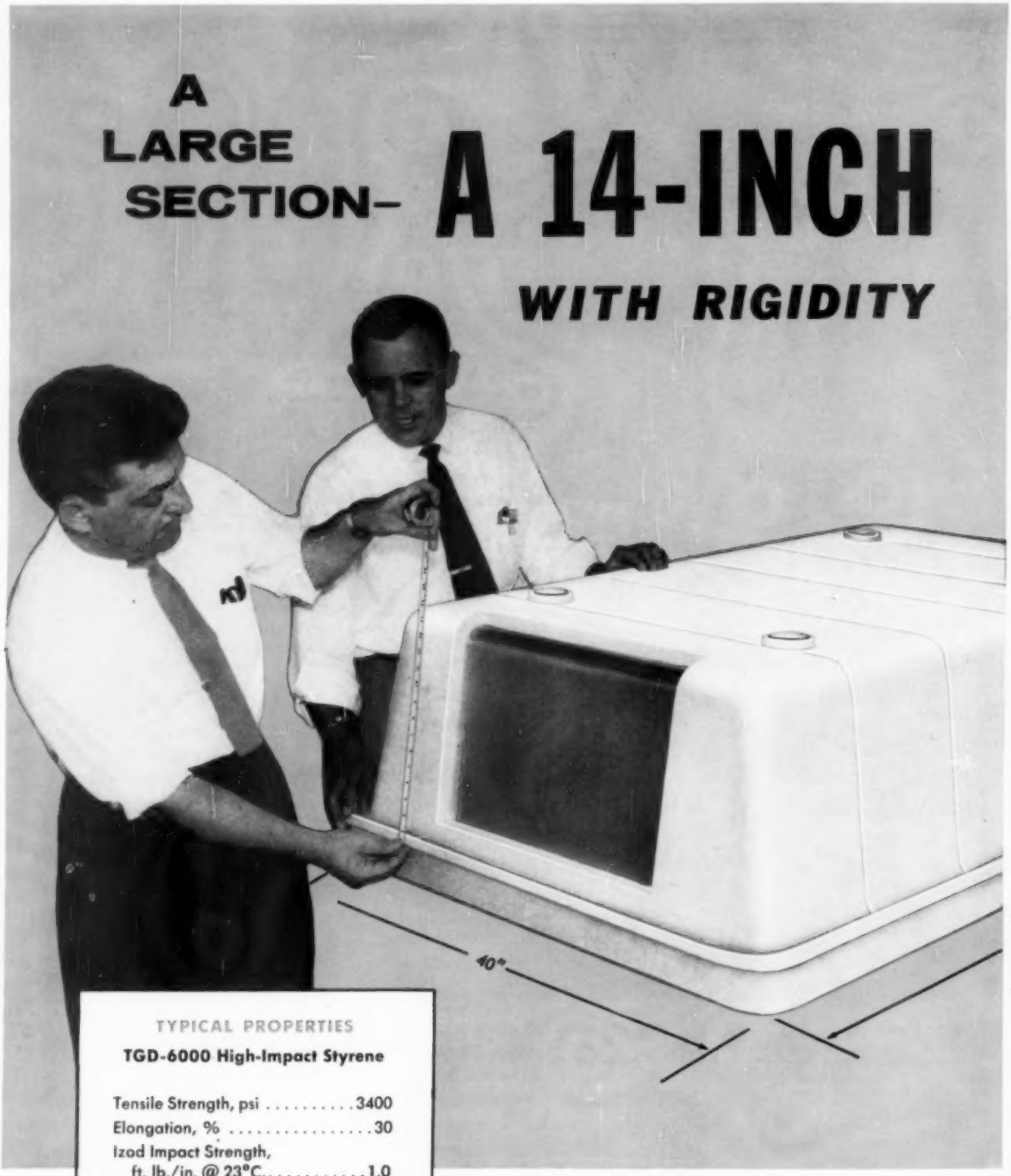
A LARGE SECTION— A 14-INCH WITH RIGIDITY



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Flexural Strength, psi	8000
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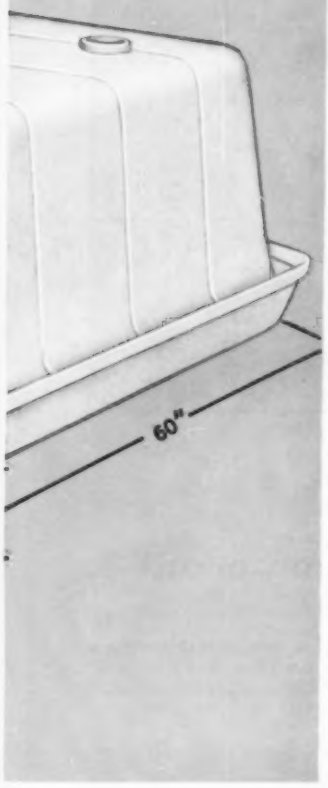

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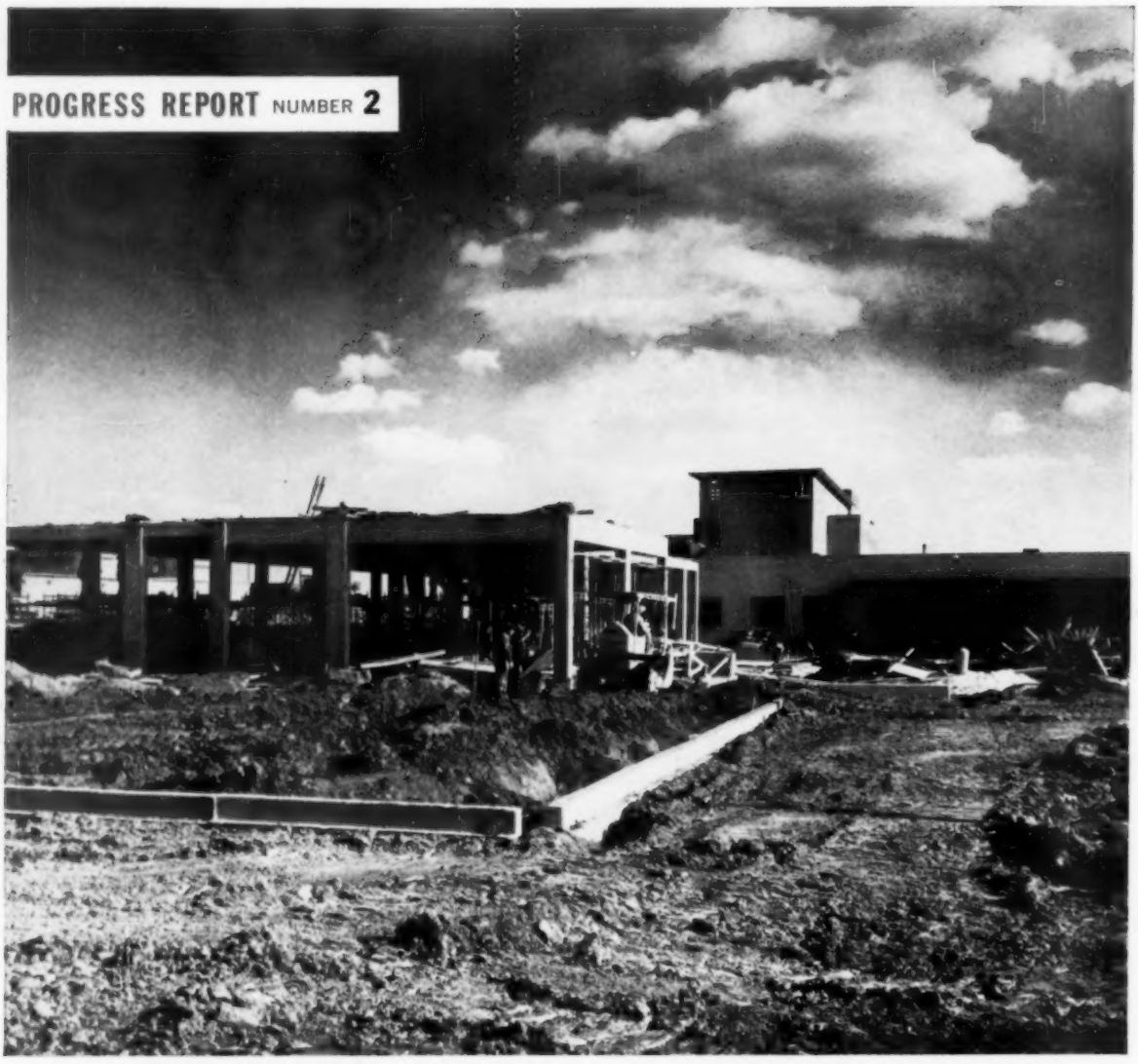

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Charles E. Rhine
Editor

EDITOR'S NOTEBOOK

Now is the time!

SUBMIT PAPERS for 16th ANTEC

January 12-15, 1960
The Conrad Hilton
Chicago, Illinois

Your 1960 ANTEC General Chairman, Frank Fine, and your Program Vice Chairman Chuck Waugh, as well as the Executive Committee and the various Committee Chairmen, are already hard at work to develop a darn good Conference for your technical satisfaction. The backbone, and only criterion of success for such a conference, is the selection of papers written by YOU. Your help will make this the biggest and best ANTEC ever!

The 15th ANTEC in New York, sponsored jointly by the Newark and New York Sections just a short while ago in January, contained a topnotch selection of technical papers including some on subjects never before presented in an open meeting in this country. The high technical quality and smooth organization of this Conference was a tribute to Co-Chairmen Jim Growley and Guy Martinelli and their Committees.

So, while the papers from the last ANTEC are still in your mind, and you are studying and discussing them, jot down the ideas you had in January for needed papers that occurred to you, then under that stimulus, decide which you can present and let us know *now*.

It's not too early! Within a few months, this summer, we'll be needing abstracts; and a few months after that, early fall, the completed papers should be in. Not much time is there?

Notices will be in the mail shortly to all SPE members requesting papers and suggestions. Please reply to me at the address given below.

THANKS FOR YOUR HELP!

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SPE 1960 Annual Technical Conference
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DOW'S CLINICAL APPROACH TO HEALTHY PLASTICS APPLICATION

PROPER CLASSIFICATION AND USE OF DATA VITAL TO SUCCESSFUL PLASTICS PERFORMANCE

FIVE BASIC DATA TYPES DEFINED

Proper classification and use of available data is one of the most important steps in developing good plastics design and engineering data. Vast differences in the five data types as defined by Dow Technical Service engineers (see chart at bottom of page) make it imperative that care be taken to insure their correct application.

For example, identity data are normally of no value in screening, quality control, engineering or design. At the same time, quality control data should not be applied where design or engineering data are required by the problem being studied.

Generally speaking, quality control, screening and identity data fuse together into the area of *routine testing*. They are characterized by the need for speed and reliability and are often based upon test methods far removed from basic design and engineering.

Engineering and design data, on the other hand, are generally more expensive, time consuming, fundamental and of broader applicability than any other forms of data. They should not be considered in the area of routine testing, but as representing *materials engineering* in its fundamental form.

Successful research, development, production and application of new materials can be greatly hindered by the unwitting transfer of data or methods from testing into materials engineering. And yet, examples of misapplied data have occurred with enough frequency to indicate a potentially serious trouble spot in the industry.

To help combat this problem, technical service engineers at Dow are compiling comprehensive design engineering data and principles tailored for the design engineer. This data, the result of continuing studies which Dow conducts in the interests of the plastics industry, should clarify many areas of possible confusion on the use of plastics data. Future Plastiatrics articles will present this data as it is developed. THE DOW CHEMICAL COMPANY, Midland, Mich., Plastics Sales Department 2100EX3.

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STYRON 440 (Heat Resistant)
STYRON 440M (Easy Flow)
STYRON 480 (Extra-High Impact)

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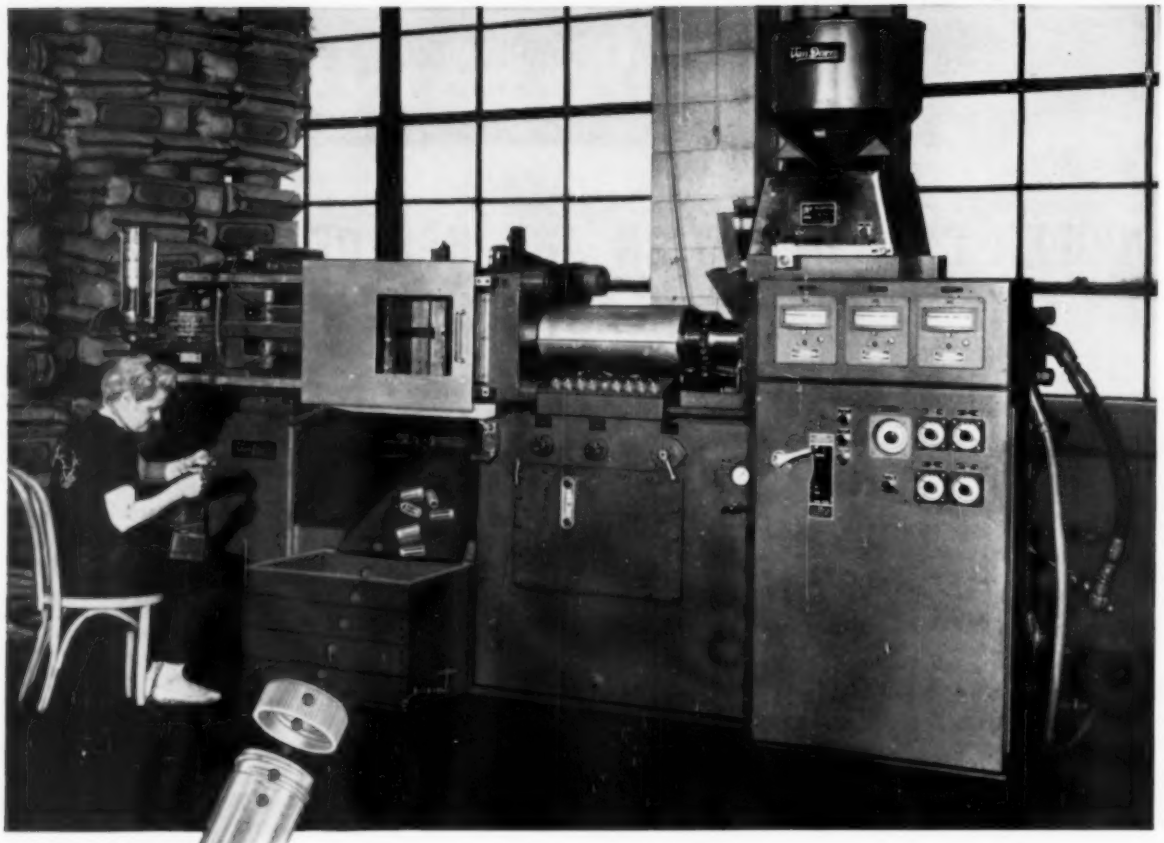
STYRON 683
STYRON 700

TYPE OF DATA	DEFINITION	EXAMPLE
DESIGN	Those data on materials which permit the design of a new item or improved design of an existing item through proper choice among materials and calculations of the size and shapes required for satisfactory performance.	The tensile strength of specimens made from a given material as a function of time, temperature and environment.
ENGINEERING	Any data relating to the intended performance of a complete item or portion of that item irrespective of the materials from which it was made.	The bursting strength of a pipe as a function of time, temperature, and environment.
QUALITY CONTROL	Any form of test data relating to predetermined levels of acceptable quality to manufacturing conditions.	The melt viscosity of a plastic under specific and prescribed test conditions.
SCREENING	Those data which rank similar products or materials in order of preference for a given characteristic regardless of specific end-use requirements.	The ranking by density of expanded plastics.
IDENTITY	Results of tests which establish the identity, grade, type, purity or composition of a product among otherwise similar products.	The detection of chlorine in polyvinylchloride (PVC).

THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN



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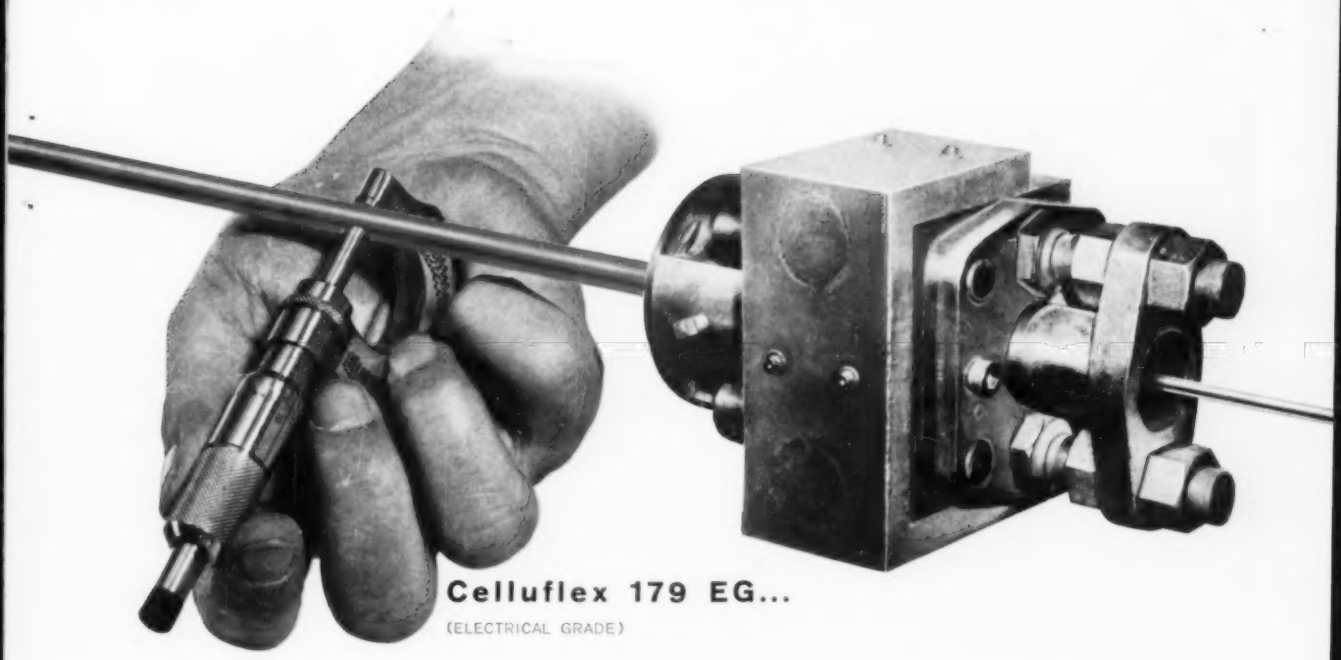

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Greater latitude in radio cabinet design is permitted by the higher heat resistance of CYMAC® 400 polymethylstyrene plastic which will withstand continuous service at temperatures to 212°F without distortion. This property, plus its ready adaptability to complex molding and its excellent flow and color characteristics, was one of the reasons it was selected for the cabinet of the RCA Victor table radio, *The Burgess*, illustrated here.

Additional advantage of CYMAC is that it has sufficient flexibility for back cover to be secured without fasteners: a simple snap-fit reduces cost, speeds assembly, and facilitates disassembly if required. The following properties indicate CYMAC 400 is an ideal material for radio cabinets and similar housing requirements:

Resistance to heat, °F (cont.)	212
Heat distortion temperature, °F	213
Molding shrinkage, in./in.	.0046
Specific gravity	1.02
Flexural strength (1 in./min crosshead speed)	12,500
Impact strength ft/lb/in. of notch (½ x ½ in. notched bar, Izod Test)	.30
Rockwell hardness	76M
Dielectric strength, short time, ⅛ in. thick volts/mil, 1/16 in. disc	890

CYANAMID

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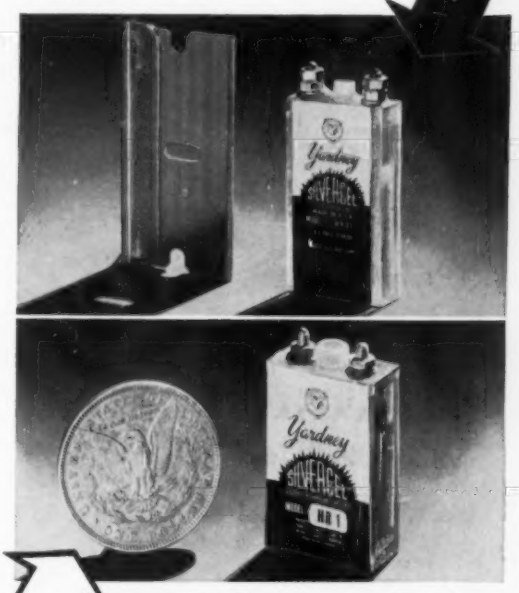
World's smallest and lightest rechargeable battery cell, shown here with razor blade, is Yardney Electric Corporation's HRO1 Silvercel®. Designed primarily for use in instrumentation and telemetering packages for missiles and rockets, it has a 3 amp peak pulse discharge and weighs less than one-seventh ounce – thanks in great part to lightweight molded CYMAC SUPER* 201 thermoplastic case and cover.

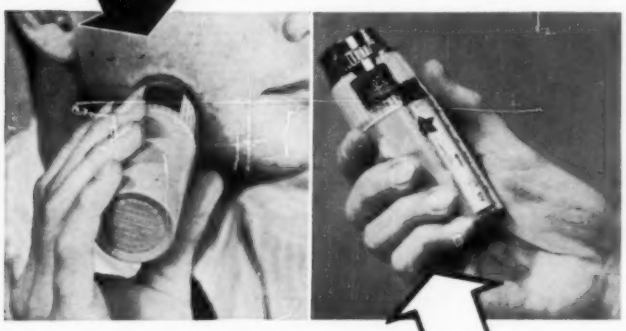
*Trade mark



Another Yardney silver-zinc cell is shown here with a silver dollar for size comparison. This HR1 Silvercel® delivers a 45 amp peak pulse discharge yet weighs only ¾ ounce. CYMAC SUPER 201 methylstyrene-acrylonitrile copolymer was selected because of its:

- Low specific gravity (1.06)
- Exceptional combination of high tensile (11,000 psi) and high flexural (16,100 psi) strengths
- Heat resistance (distortion point 211°F)
- Complete resistance to concentrated potassium hydroxide electrolyte
- Excellent injection molding characteristics, transparence, resistance to crazing, and ease of solvent-sealing covers to cases.

New cordless electric shaver features light weight (two ounces), damage-resistant case of CYMEL® melamine plastic, designed by Raymond Loewy Associates. This smart-looking Universal shaver operates anywhere on ordinary penlight or transistor batteries. The CYMEL case is contoured to fit the hand, corrugated at the top for a natural, easy grip.



Battery and motor unit are secured by light press fit in housing compression molded of CYMEL 1079 melamine molding compound. CYMEL resists breaking, chipping, scratching, perspiration, and corrosion from shaving lotions and battery chemicals. It provides a rich look and warm feel. Color, molded in, can't chip or wear off. Molded by Holyoke Plastics Company, Holyoke, Mass., for Landers, Frary & Clark, New Britain, Connecticut.

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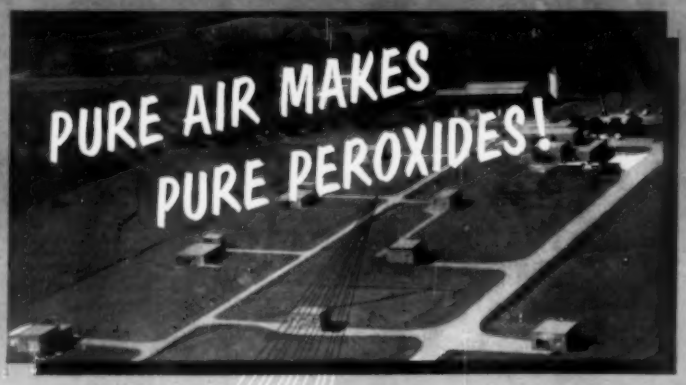
TYPICAL CHARACTERISTICS-LAMINAC 4106

Viscosity*	5 poises
Specific gravity	1.1
SPI cure characteristics	
Gel time	3½ minutes
Time to peak temperature	5½ minutes
Peak exotherm temperature	400°F

*Brookfield Model RVF, spindle #1, 10 rpm 77°F



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Elongation (%)	D638-52T	48—63
Flexural properties:		
Flexural strength (p.s.i. at break)	D790-49T	3300—10700
Rockwell hardness: (R scale)	D785-51	−15 to 106
Izod impact: (ft. lb. in. notch)	D256-43T	1.2—11.0
Heat distortion: (°C.)	D648-45T	51—70
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d
ZYTEL 109* is a new composition having a lower melting point, lower processing temperatures, and greater flexibility than ZYTEL 101. Particularly suited for thick sections, it molds on fast cycles and has low mold shrinkage.

*New commercial code for FE-2307

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NEW SURFACE COLORING METHODS... New information is available on the surface coloring of parts made of ZYTEL. Cleaning of surfaces represents a negligible problem when no lubricants or mold release agents are used. Recommendations for correct primer coating and its application may be made. Topcoat adhesion of enamels is found to be excellent. The newer finishes, such as LUCITE® acrylic lacquers, are readily usable. Such painting is useful in putting designs on finished pieces, markings on business-machine dials and for similar applications.

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PLASTICS ENGINEERS JOURNAL

Volume 15, Number 3, March, 1959

Materials for Long Range Missiles and Space Vehicles

Advancing developments in missile design have established requirements beyond available materials. This means that the engineer must utilize the materials he has to the best advantage until the materials researchers develop modifications or new materials which satisfy these requirements.

William A. Mrazek
Army Ballistics Missile Agency
Structures and Mechanics Laboratory

THE Army Ballistic Missile Agency is responsible for prosecution of the Redstone Missile Program; the development of an Intermediate Range Ballistic Missile, the Jupiter; the development of a medium range, solid-propellant missile system, the Pershing, which will eventually replace the Redstone; and for certain earth satellite missions.

The Army Ballistic Missile Agency organization is unique in government service in that the complete cycle from the idea for a missile through the design, manufacture, static testing, flight testing, and flight evaluation is accomplished by the agency. In fact, this is the only installation in the United States capable of pursuing a missile project from design through prototype production.

Because it is concerned with missiles and space vehicles from "concept to proving ground," successful accomplishment is dependent upon team effort. An important position on the team must be occupied by materials specialists in industry, as well as in government; by raw materials suppliers; material processors; and fabricators. The plastics industry has an obligation to develop new materials and techniques and to modify existing ones to enable the designer to meet the stringent design criteria imposed by mission requirements.

This article is based on a luncheon speech given during the 15th Annual Technical Conference of SPE in New York City.

IMPORTANCE OF MATERIALS

The importance of materials in the missile field would certainly not be disputed by an engineer. The two things which limit missile design more than any other factors are the lack of materials suitable for missile and space vehicle application and the lack of adequate processing or manufacturing techniques.

The importance of materials research in the missile field can be emphasized by calling to mind some of the criteria for missile design. These criteria will also suggest the problem areas which we will consider shortly.

1. 100% reliability.
2. Materials of high-strength-to-weight ratio.
3. Materials suitable for use with highly corrosive fuels and oxidizers.
4. Launching in sea coast climatic conditions.
5. Long-term storage and the capability of being launched with minimum reconditioning.
6. Relative ease and reliability of fabrication.
7. Nominal cost.

PROBLEM AREAS

Reliability

Many problems result from the requirement for reliability. In the past, some have had the impression that inasmuch as missiles were not carrying personnel, reliability was not a problem. Nothing could be farther from the truth. First, missiles, especially test missiles with all the extra instrumentation, are very expensive. Second, since the missile does not carry personnel, no repairs can be made after take-off. Thus, the failure of one small part of a small component may result in failure of the missile. In this light, problems which may have eluded all but the materials engineer take on an entirely justifiable significance. For example, a problem which has occupied us for years is the bonding of rubber to metal with a bond strength superior to the strength of the material itself. This problem may appear minor as compared to a large missile, but its importance cannot be over estimated. One bonding failure of a seat on a valve in a control mechanism can cause loss of the entire missile. This fact alone justifies the extended research put into the fields of rubber, plastics, and adhesives.

Strength-to-Weight Ratio

Current missile structural requirements demand the ultimate strength-to-weight ratio; and, the designer, as a general rule, looks first at the strength-to-weight ratio of a prospective material.

Three possible materials for missile construction are: 5052-H32 aluminum, titanium (MST 6A1-4V) annealed, and one glass fiber laminate, which I will designate Type III. The density of the aluminum sample is 0.097 lb./cu. in.; corresponding density of the titanium sample is 0.160 lb./cu. in. and of the glass fiber laminate is 0.072 lb./cu. in. The ultimate strength of the three samples is 34,000 psi for the aluminum sample, 150,000 psi for the titanium sample, and 105,000 psi for the glass fiber sample Yield strength for the three samples is 27,000 psi for the aluminum sample, 140,000 psi for the titanium sample, and 105,000 psi for the glass fiber sample. Yield strength-to-density ratio for the three samples is 278,000 for the aluminum sample, 875,000 for the titanium sample, and 1,400,000 for the glass fiber laminate.

This comparison indicates the attractiveness of glass fiber reinforced plastics to the structural designer when considered on the basis of strength-to-weight ratio alone. However, much remains to be learned about the behavior of glass fiber reinforced laminates under cyclic or flexual loading before the missile designer is able to utilize these materials with confidence. Such basic studies on materials we already have would certainly be worthwhile.

Propellant-Related Materials Problems

Fuels and oxidizers used as propellants for ballistic missiles and space vehicles introduce a multitude of materials problems. Such liquid oxidizers as liquid oxygen (LOX), fuming nitric acid, hydrogen peroxide, and fluorine, and such proven fuels as hydrocarbons, hydrazine, and ammonia pose their own special sets of materials problems.

In addition, the propulsion engineer is not always able to use the optimum combination of fuel and oxidizer because of the problems involved in containing and transferring liquids.

As an example, let us consider briefly some of the problems introduced by the Redstone propellants: liquid oxygen, alcohol, and hydrogen peroxide.

It is difficult to find a more concentrated oxidizer than liquid oxygen. Its physical condition, however, causes a lot of difficulties, since the liquid boils at −183°C, resulting in quite a loss of liquid in the case of insufficient insulation. Of course, insulation imposes a weight penalty which is undesirable. Only three or four metallic materials are suitable for application at LOX temperature: aluminum, austenitic stainless steel, copper, and, perhaps, magnesium. A further problem is that traces of organic materials on metallic surfaces or organic materials in components such as valves or gaskets can react explosively with LOX under condition of impact. In one instance while LOX was being transferred through an aluminum valve and pipe, the valve blew into pieces and the aluminum pipe burned like a wick. The only explanation which could be found for this accident was an oily fingerprint on the aluminum valve. There have been missile explosions in which lubricants or sealants were involved. In our application, all material which must contact LOX is chemically cleaned, and when it is necessary to use organic materials, these are selected on the basis of an impact test. That is, a sample of the material is submerged in LOX and an impact force is applied to the sample. A limit of insensitivity has been established to qualify these materials as reasonable risks.

An instrument for determining the LOX impact sensitivity of materials has been developed at ABMA. This instrument is being utilized now in other laboratories throughout the country. While relying on the results obtained with this instrument, we have never had an accident with LOX. This problem of qualifying materials for use with propellants is one in which much work remains to be done. Plastics are at a great disadvantage for application with LOX; however, there are plastics which are being used currently with this oxidizer.

The Redstone fuel (alcohol—75%; H_2O_2—25%) is easily handled; however, it is very corrosive to steel and light metals. The mixture is more corrosive than either of the components alone. This corrosion problem is more evident in field handling than in missile use.

A high concentration of hydrogen peroxide (76%) is used to obtain for a short time the large amount of high pressure steam necessary to drive the turbopumps which feed the propellants into the combustion chamber. The instability of H_2O_2 makes it necessary to use metals of comparatively low strength for missile tankage. In the interest of weight saving, it would be desirable to use high strength material for these pressure vessels. This appears to be possible only if a coating material, resistant to H_2O_2 can be developed. Such a coating is being developed, and results to date are quite favorable.

Oxidizers and fuels also cause problems with gaskets, washers, O-rings, valve seats, lubricants, etc., since most of the oxidizers and many of the fuels attack the usual organic materials. Plastics such as Teflon and Kel-F and the oil- or grease-like polymers of the Fluorolube type have been utilized widely as chemically resistant materials; however, they are not suitable for every application. Many plastics researchers can be kept busy developing materials which would be suitable for use with various oxidizers and fuels.

Test setups in which corrosion effects on possible missile materials are greatly accelerated are one help

in determining corrosion resistance of materials. Such tests should not be conducted in place of tests in the actual environmental conditions where it is expected that missiles will be stored or launched. Long-time environment tests and accelerated corrosion tests should be the concern of the materials developer dealing with corrosion resistant materials.

Temperature Problems

Although I have suggested the existence of materials problems at sub-zero temperatures, up to this point I have not mentioned the high temperature problems inherent in the missile field. In missiles, we have three types of heat problems: (1) those associated with the airframe, (2) those associated with the rocket motor, and (3) those associated with the re-entry body. In the first two cases, the problems vary with application, but the problem can usually be solved without using exotic material.

Fortunately for the missile designer, high temperature exposure is of short duration, of the order of a few minutes at most. This means, of course, that a material can be applied for much higher stress levels at short-duration high-temperature exposures.

Unfortunately, very little data of this type are available. Short time in the literature means 30 minutes or 15 minutes, at the least. The short exposure time has allowed many metals to be used beyond their normal operating temperatures and has allowed glass fiber reinforced plastics to be used at temperatures well above the decomposition temperature of the resins under equilibrium conditions. For example, jet vanes and rocket nozzles have been made of reinforced plastics.

The third type of heat problem, and the one which dwarfs all others, is the problem of aerodynamic heating when the missile re-enters the earth's atmosphere. This problem is the type which is of immediate interest to you. A long range ballistic missile is, in effect, a meteor: it is hurled into upper space, and then falls back at high speeds into the denser lower atmosphere. The denser lower air will slow it, but the body will also heat and perhaps burn up. Some way must be found of absorbing, draining off, or neutralizing this heat so that the missile can re-enter the earth's atmosphere intact. There are several approaches to the problem. These include (1) insulating and maintaining an extremely high surface temperature by means of ceramic skins, (2) film cooling where a liquid is exuded through the skin to cool the outer layer, (3) using higher-temperature alloys (yet to be devised), (4) increasing the thickness of the missile's skin or choosing a high heat capacity material to provide a heat sink, and (5) providing a material whose melting or decomposition can be controlled in such a manner that heat is dissipated.

In addition to the high temperature problem, some problems are in the sub-zero region, as indicated earlier in the discussion of materials suitable for use with LOX. In operation at ABMA is a testing device to measure sub-zero mechanical properties of certain alloys for which data are unavailable.

In addition to high-temperature properties and low-temperature properties, there are still other applications in which missile structural materials are subjected to severe thermal cycling: for example, an orbiting satellite as it continually passes from the earth's shadow into the sunlight and into the shadow again.

A FORWARD LOOK

This is but one of the problems brought on by the advent of the "space age." Indeed, the materials engineer has been faced with a whole new set of problems based upon the conditions which will be encountered in outer space. One major source of difficulty is the lack of information on exactly how serious the environmental conditions may be. One may list the adverse conditions of outer space as being primarily (1) temperature extremes, (2) high vacuum, (3) solar radiation, (4) cosmic radiation, (5) residual gases, and (6) meteor bombardment.

The problem of radiation damage may be more serious in polymeric and other organic materials such as special paints, organic sealants, and lubricants than in the case of pure metals. Any hydrocarbon after irradiation will turn into an inextricable mixture resembling petroleum in its general constitution. Polymerization dehydrogenation, and cracking may also occur. It has been shown that polymethyl methacrylate is broken up by high energy radiation. Internal bubbling occurs as a result of decomposition, and gases are liberated which may diffuse. Rubbers become hard and brittle in some instances and in others oily and tacky. Other materials such as polyvinyl alcohol, gutta percha, neoprene, and polystyrene have been shown to become cross linked under radiation. Irradiation of polyethylene causes cross linking and formation of a new polymer having a higher melting point and greater resistance to chemical attack. In some cases properties are improved. In other cases, the materials are essentially destroyed.

It has been shown that certain organic materials can act as protective agents in competing for degradative radicals occurring after chain rupture. Much more work is required along these lines.

The advances in the missile and satellite fields have also placed upon the materials engineer the requirement for paints and other surface coatings of highly specialized properties. Coatings having a specific reflective-absorptive ratio are required as well as ice phobic coatings and paints of low weight. Paint already constitutes a weight problem. In orbiting bodies, in particular, special care must be given to developing paints with good resistance to the degrading effects of intense solar radiation. Here again cosmic radiation may also play an important role in destroying the paint vehicle or at least changing its special properties.

Another area of great interest is in the thermal properties of materials under influence of the extreme cold of outer space and the high heat flux of re-entry conditions. Here again is another aspect of material technology wherein the literature is of little aid, and where much remains to be done.

CONCLUSIONS

In summation, one may say that advancing missile designs have established requirements beyond the properties of all commercially available materials. The missile engineer has but one alternative while awaiting advancement in the materials field. He must align himself with the designer and the fabrication specialist to devise means of utilizing the materials he has to the best advantage. This may require composite materials and unorthodox designs, fabrication techniques, and materials application, but it is the most expedient means of advancing missile design while we are waiting for you materials researchers to extend the horizon by modification of available and development of new materials.

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Pitfalls in Evaluation of PVC Stabilizers

Here are some rules for testing vinyl stabilizers. They were developed through long experience, and only by a careful analysis of each step presented here can a choice be made which will result in superior quality and reduced cost.

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Ferro Chemical Corp.

VIRTUALLY ALL INGREDIENTS, used in the production of polyvinyl chloride end-products, must pass frequent, strongly competitive evaluations, if they are to survive in the market.

These evaluations are conducted by the manufacturers of the individual ingredients of the final mix, by their customers, and by many other service laboratories.

In the case of stabilizer evaluation, the problem is generally: Given a particular formulation with a known content of *specified* resins, plasticizers, fillers, pigments, and other additives, to be processed under some *specified* conditions, what stabilizer is best suited to provide some *specified* degree of stability?

It is not normally within the province of the stabilizer evaluator to suggest that substitution of one resin for another, or one plasticizer for another, etc., would, in effect, improve ultimate stability. The choice of resins and plasticizers depends on many factors of which stability is but one. Nevertheless, these ingredients do make their own individual contribution to stability or instability.

Thus, the stabilizer evaluator is confronted with a situation in which many variables which are known to affect stability are already fixed. It is his duty to find the stabilizer which will take advantage of those factors already in the formulation, which hinder degradation; and to counteract those factors which promote degradation.

In picking his way among the many ingredients and processing conditions which determine the final product, the evaluator risks many pitfalls which could lead to an erroneous, and, therefore, excessively costly choice. Some of these pitfalls are discussed below:

The Pitfall of the Changing Resin

For perfectly good and sound reasons, many vinyl processors use more than one resin. These resins are often chosen so that switching from one to another in processing, will require a minimum of change in operating conditions. When stabilizers were at an earlier stage of development, similar resins could be readily presumed to have similar stabilization requirements. But, with increasing stabilizer efficiencies, the effort is made to exploit every subtle difference in resins (and other raw materials) to secure optimum stabilization.

Thus, the responsiveness of the different resins to metal-organic compounds has now been extensively studied. This is particularly true of responsiveness to zinc-containing stabilizers. Resins are neither better nor worse for responding to zinc stabilization. But, optimum stabilization is obtained only by understanding their individual characteristics.

Reputable stabilizer suppliers can help their customers (on the basis of laboratory and field experience) in adjusting stabilizer systems to meet changes in resin supplies.

Stabilizers should be checked against known changes in resin.

The Pitfall of Filler

While most calendered and extruded vinyls are opaque, filled stocks, many evaluatory tests are carried out in clear formulations. This practice had, and has, some logical basis. Certainly degradation color changes are more readily detected in clear formulations than in opaque stocks. And, in many systems, particularly using older types of stabilizer, the filler, or pigment, is so inert, that relative stabilizer ratings could readily be transferred from one system to another. Here again, however, superior stabilizer systems attempt to make every ingredient in the system work at maximum efficiency. Under present processing conditions, the fillers can often be made to work synergistically with stabilizers to achieve remarkable effects. Thus, very often zinc-containing stabilizers contribute long-term stability in filled systems, while they reduce long-term stability in clear systems.

Proper stabilizer selection means best utilization of the filler.

The Pitfall of the "Typical" Formulation

In order to illustrate the performance of resins or plasticizers or fillers, suppliers of these materials often publish "typical formulations." These guideposts can be used to advantage, only in connection with a sound stabilizer evaluation program. This is particularly true when one takes into account the wide range of compositions and performances which are encompassed in oft-repeated suggestions "Ba-Cd stabilizer 2 phr." Not

only do barium and cadmium contents vary widely, but the other ingredients which make up the stabilizer formulation exert their own extremely important influence. Thus, while published "typical" formulations might well serve as a starting point for stabilizer evaluation, they can rarely, if ever, be regarded as a final recommendation. One leading stabilizer manufacturer has at least eight Ba-Cd stabilizers in active production, and others suitable for special applications, each with distinctive properties and heat and light stabilization characteristics.

Stabilizers differ; they cannot be bought by specification alone, they can only be selected on the basis of performance.

The Pitfall of Testing in Sequence

Not so long ago gross differences between competitive stabilizer performances were quite common. These great differences are still observed, but much less often.

When looking for big differences there was no problem in reproducibility of tests. What was good was good; what was bad was bad. Nowadays one looks for less easily noted differences. This has necessitated simultaneous testing of competitive systems, rather than testing in sequence.

The reason for this becomes evident if one considers the degradation rate as doubling for every 10°C rise in temperature. A variation of 3°F would, therefore, cause a difference in 10 minutes in performance rating in a 2-hr. oven heat test. Despite continually improved design of ovens, it is difficult enough to insure that samples in the same oven will have the same temperature to within 2°F. It is correspondingly more difficult to duplicate heat history when the test samples are not run simultaneously.

These seemingly small differences have become increasingly important. A variation of 10 minutes in a two-hour heat test often implies a 10% difference in stabilization cost.

All competitive heat tests should run simultaneously.

The Pitfall of the Unknown Standard

With some stabilization systems, the compound appears to be reasonably unchanged by heat or light until some critical point is reached, at which time discoloration appears and spreads rapidly. For such systems, it is frequently possible to specify time, temperature, light exposure, etc., and to evaluate stabilizers on a yes-or-no basis. However, for most stabilization systems the development of discoloration is quite slow, without sudden failure, and the minimum acceptable degree of stabilization is often difficult to define precisely. It is thus necessary to run the test stabilizer system against a standard. Unless there is a realistic standard (usually a similar system but embodying different stabilizers or the same stabilizers at different concentrations), the results of the test are of very little value.

All tests, to be meaningful, must be run against a standard.

The Pitfall of "Long Long Term"

It is true that for most stabilizer systems, the use of more stabilizer increases the stability of the product. When stabilizer types were fewer than they are nowadays, a reasonably good judgment could be obtained by prolonged heat-testing. Such long tests would accentuate the difference between stabilizers.

The stabilizer types now available differ so markedly in their curves of discoloration vs. time, that the best stabilizer, judged for a "long long term" (e.g., more than 2 hrs.) may be quite mediocre compared with another stabilizer in a 1 hr. test. The decision as to a realistic heat requirement will carry with it, therefore, important implications not only on the amount of stabilizer to be used, but also on the kind of stabilizer.

Typically many of the solid "Ba-Cd" stabilizers are superior in heat tests lasting 2-4 hrs., while the better liquid "Ba-Cd" stabilizers are superior in tests ranging from 30 minutes to 2 hrs.

An important problem here is the rework factor. If we assume in a calender a theoretical minimum heat history of about 20 minutes and a maximum rework percentage of 25%, we have the following limiting set of conditions:

- 75% of the product will have been processed for 20 minutes.
- 18.7% of the product will have been processed for 40 minutes.
- 4.7% of the product will have been processed for 60 minutes.
- 1.2% of the product will have been processed for 80 minutes.
- 0.3% of the product will have been processed for 100 minutes.
- 0.1% of the product will have been processed for 120 minutes.

Thus, even under the unfavorable operating conditions which are represented by this table, the amount of material which is processed for more than 2 hrs. is so small, that even if it were discolored, the dilution effect would probably render it entirely undetectable.

Typically, operations are more efficient, and heat history beyond 1½ hrs. does not correspond to a real problem in most applications.

Unneeded long term stabilization may be costly, and may be purchased at the expense of other desirable properties.

The Pitfall of "Multiple and Single Packages"

The flexibility of the multiple package system is certainly advantageous in many instances. This is generally counterposed by the inventory and handling economies of the one-package system What is frequently overlooked, however, is the *chemical* difference which often exists between one- and two-package systems.

Thus, good Ba-Cd stabilizers are not *mixtures* of barium and cadmium stabilizers. The conditions of their preparation are such as to secure a stabilizer which does the job better than a simple mixture could possibly do. As the mixtures become more complex, the importance of controlled interaction between the stabilizer components becomes increasingly the key to effective, economic stabilization.

Often the compounds which appear in single package systems are not known in the pure form, or can be prepared as pure substances only with great difficulty. Commonly, because of commercial competitive considerations, their chemical compositions are not described in chemical literature.

Good stabilizers perform better than mixtures of their raw components.

(*Continued on page* 219)

CASTABLE CONDUCTIVE PLASTICS

Commercial polyester resins filled with ammonium perchlorate and graphite produce a series of combustible conductive plastic materials. Volume resistivities as low as 0.7 ohm-cm are obtained from essentially noncombustible composition containing approximately 50% graphite. Improved combustibility and a volume resistivity of 6 ohm-cm are obtained from a composition containing 20% ammonium perchlorate and 30% graphite.

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A COMBUSTIBLE conductive plastic material was required for an Army Ordnance application. The prime requirements for this material were: (1) complete combustibility and (2) a volume resistivity of less than 10 ohm-cm.

It is known that the electrical conductivity can be achieved in polymers by incorporating electrically conductive fillers such as metal powders or conductive carbon blacks. In addition, the burning characteristics of a polymer can be altered by incorporating oxidizers such as perchlorates. In each case the properties of the system will be a function of the amount and the properties of the plastic binder and the incorporated filler.

Polyester resins were selected as the plastic binders for this investigation for the following reasons:

a. Polyester resins were reported (Ref. 1) to have lower volume resistivities than some of the other candidate materials.

b. Polyesters are combustible in air.

c. Polyesters can be cured at room temperature and are adaptable to casting as well as to molding compounds.

Some of the variables which were found to influence volume resistivity of the conductive composition are:

Composition of the Polyester Resin

Table I shows the variation in volume resistivity of three castings, each made with a different polyester resin. The resins employed in this study were proprietary materials of the unsaturated polyester, styrene modified type.

It may be seen from Table I that volume resistivity of the casting depends upon the chemical composition of the polyester resin, the resistivity being the highest with the flexible polyester. Since the addition of filler and styrene monomer to the rigid polyester caused embrittlement, the flexible polyester was employed in subsequent investigations.

Additional Styrene Monomer

Additional styrene monomer was added to the flexible polyester resinous system to reduce the viscosity to accommodate larger quantities of filler and to maintain sufficient mobility in the resin systems to permit casting. The addition of styrene monomer affected the volume resistivity as shown in Fig. 1.

Type and Amount of Conductive Filler

The type and amount of conductive filler incorporated is the chief factor in determining the electrical conductivity of the system. One theory offered to explain electrical conductivity of systems such as are studied in this paper assigns the conductivity to the conductive filler particle-to-particle contacts. Dispersed fillers result in a multiplicity of paths along which current can flow. The electrical conductivity, then, depends largely upon the inherent conductivity of the filler, the resistances of the filler particle-to-particle contacts and the concentration of the filler. For this investigation a non-metallic filler, graphite, was selected to eliminate the possibility of an abrasive residue after combustion. Other conductive non-metallic fillers such as furnace or acetylene blacks may have been used, but these generally yield higher and more variable resistances than the graphites. Fig. 2 illustrates the change in volume resistivity observed with varying amounts of graphite filler. It should be noted that the minimum volume resistivity is approached when the weight ratio of binder to graphite is 1:1. Hence, little change in volume resistivity can be expected by adding more graph-

TABLE I

Variation of Volume Resistivity Obtained with Different Polyester Resins

Resin Used in Base Formula	Volume Resistivity of Casting
rigid commercial polyester	4.81 ohm-cm
" " "	5.76 ohm-cm
flexible commercial polyester	6.54 ohm-cm
Base Formula	**Parts by Weight**
polyester resin	33.0
added styrene monomer	25.0
Grade I graphite*	42.0
MEK peroxide	2.0
cobalt naphthenate (6.0%)	0.50

*Grade I graphite as designated in JAN-G-155.

[1] "Plastics Property Chart," *Modern Plastics Encyclopedia*, Plastics Catalogue Corp., Bristol, Conn. (Sept. 1956).

TABLE II

Effect of Graphite Particle Size on Volume Resistivity

Graphite Used in Base Formula	Average Particle Size	Graphitic Carbon Content	Volume Resistivity of Casting
electrical grade graphite	10 microns	97-98%	3.76 ohm-cm
" " "	5 "	97-98%	3.53 " "
" " "	2.5 "	97-98%	2.67 " "

Base Formula Used	Parts by Weight
commercial flexible polyester	20.8
styrene monomer	59.2
graphite	20.0
MEK peroxide	2.0
cobalt naphthenate (6%)	0.5

ite to the mixture. In addition, more graphite would make the composition too viscous for casting.

Graphite Particle Size

It was found that the volume resistivity of the castings was influenced by the particle size of the filler (see Table II).

It may be observed that the smaller graphite particles yield castings of lower volume resistivity. However, using the smaller particles as filler increases the viscosity of the resinous system at a much faster rate than the volume resistivity decreases. This makes it impossible to include enough filler to yield a castable composition with the desired volume resistivity. Grade I graphite with the sieve analysis shown in Table III proved satisfactory for the formulation of castable compositions of acceptable volume resistivity.

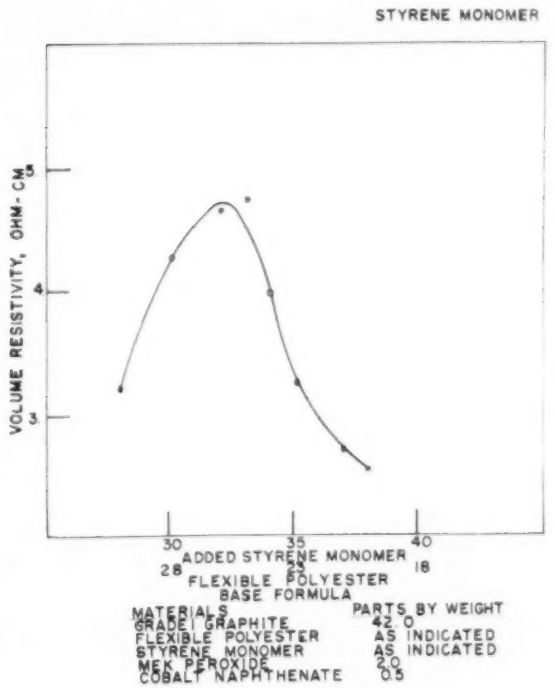

Figure 1. Variation of volume resistivity with added styrene monomer.

Amount of Oxidizer

The graphite filled castings are difficult to ignite and are self-extinguishing once ignited. The addition of an oxidizer in place of some graphite filler improves ignition and burning characteristics. A composition containing 20 parts ammonium perchlorate in place of the same amount of graphite burned smoothly to form a soft powdery ash. Fig. 3 shows the variation of volume resistivity obtained when ammonium perchlorate is substituted for graphite. It may be observed in Fig. 3 that the volume resistivity increases rapidly with the perchlorate substitution. Since 10 ohm-cm was established as the maximum volume resistivity for this

TABLE III

Sieve Analysis of Grade I Graphite

Sieve	Mass Fraction
140	0.009
200	0.025
325	0.177
<325	0.789

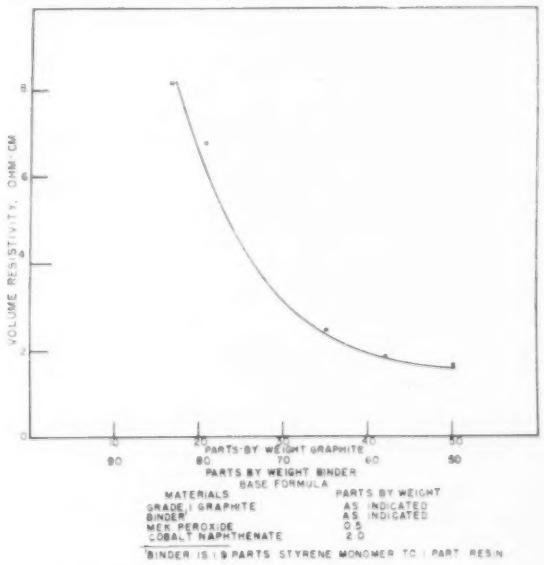

Figure 2. Variation of volume resistivity with amount of graphite filler.

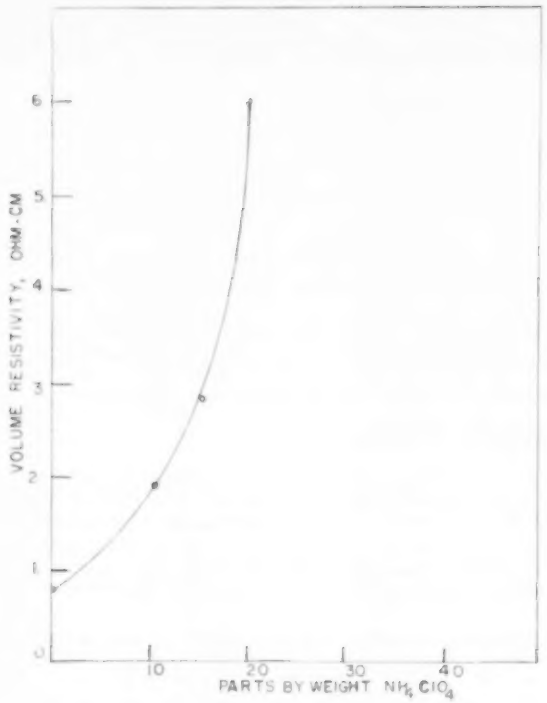

Figure 3. Effect of replacing graphite with NH_4ClO_4 on the volume resistivity.

material, 20 parts ammonium perchlorate was the maximum substitution made.

On the basis of this investigation the following castable formulation is recommended for maximum conductivity:

Materials	Parts by Weight
Grade I graphite	50.0
flexible commercial polyester	13.0
styrene monomer	37.0
MEK peroxide	2.0
cobalt naphthenate	0.5

This composition will yield castings with volume resistivities of approximately 0.70 ohm-cm. Replacement of 20 parts graphite with ammonium perchlorate produces a combustible composition that will yield castings with volume resistivities of approximately 6 ohm-cm.

This investigation was limited to castable compositions. However, molding compositions can be similarly compounded. They would yield moldings of superior conductivity since they would contain less organic binder.

Environmental factors such as temperature and relative humidity were shown to have little influence on the electrical properties of a typical casting. Compositions, both with and without the perchlorate, when exposed to extremes of humidity showed less than 1% change in weight and no decrease in conductivity. Fig. 4 shows the variation of volume resistivity with temperature for a typical composition. At 165°F the particular composition under test softened somewhat. However, the volume resistivity remained essentially constant at temperatures from —50 to +165°F.

EXPERIMENTAL PROCEDURE

Mixing and Casting

In this investigation vigorous mixing was avoided to prevent air entrapment and filler particle breakdown, both of which can give rise to inconsistent results and higher resistances. The resin, additional styrene monomer and cobalt naphthenate were blended into a uniform solution. The peroxide catalyst was added and the mixing was continued. The fillers were then added intermittently. As soon as the mixture appeared uniform the specimens were cast in rectangular-troughed plastisol molds.

Curing

Castings were put in an oven at 85°C and allowed to remain 1 hour at that temperature. In each case gelation occurred in less than 5 minutes. This prevented appreciable filler settlement. An additional 24 hours was allowed for cure at room temperature. The rectangular castings were then machined to produce specimens of exact dimensions.

Instrumentation

The circuit and jig shown in Fig. 5 were used to measure the resistance of the specimens. To avoid

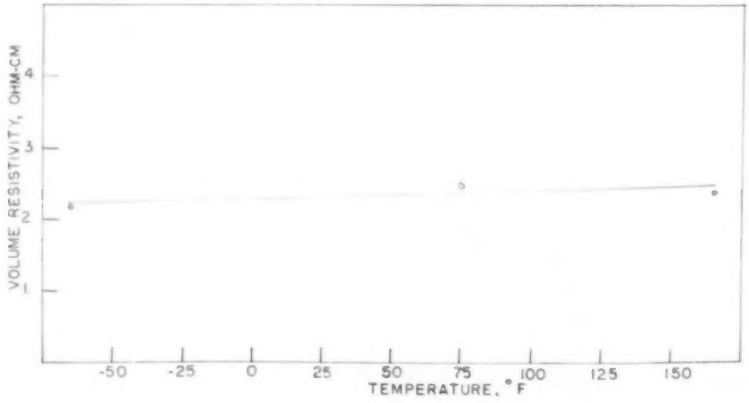

Figure 4. Variation of volume resistivity with temperature.

large contact resistances between the electrodes and specimens each end of each specimen was coated with a conductive silver paint.

The formula used to calculate resistivity, ϱ_x, was derived as follows:

$$R_x = \frac{V_x}{i} \qquad \text{(Eq. 1)}$$

$$\text{where } i = \frac{E}{R_1 + R_x} \qquad \text{(Eq. 2)}$$

When $R_1 > R_x$ assume R_x negligible in (Eq. 2)

$$\text{Then } i \cong \frac{E}{R}. \qquad \text{(Eq. 3)}$$

Substituting Eq. 3 in Eq. 1

$$R_x = V_x \frac{R_1}{E}; \text{ also } R_x = \frac{\varrho_x L_x}{A_x}$$

$$\text{or } \frac{\varrho_x L_x}{A_x} = \frac{V_x R_1}{E}$$

$$\text{Hence } \varrho_x = \frac{V_x R_1}{E} \frac{A_x}{L_x}$$

Where

ϱ_x = volume resistivity, ohm-cm.
R_1 = known resistance, ohms (10^5 ohms)
V_x = voltage drop across specimen
A_x = cross-sectional area of specimens, sq. cm.
L_x = Length of the specimen, cm.
E = emf of the battery, volts

The circuit used in this investigation does not exclude surface effects. However, the surface current in a semi-conductive material is negligible compared to the total flow. Hence, the values calculated for resistance in this investigation may be shown to correlate closely with the volume resistivity.

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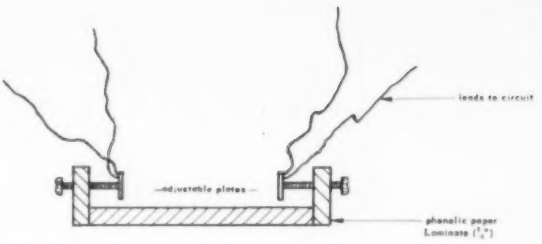

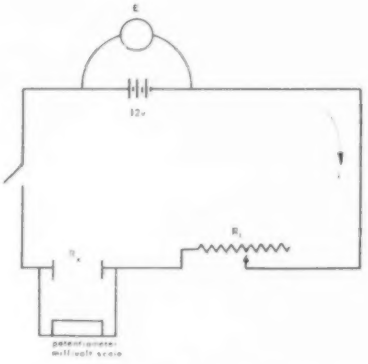

Figure 5. Jig and circuit for resistance measurement.

PITFALLS *(Continued from page 215)*

The Pitfall of "Liquids vs. Solids"

The use of liquid stabilizers affords numerous operating conveniences and economics. Nevertheless, for some formulations, the best stabilizers are not available in liquid form. The nearest liquid equivalents may, in fact, represent a stabilization cost which outweighs the operating savings in materials handling. Assigning proper weight to stabilizer costs and to materials handling may help avoid an important source of error.

Stabilizer performance often outweighs convenience of form.

The Pitfall of "Just Lubricants"

The mild stabilizing action of calcium stearate, and the absence of any stabilizing activity of stearic acid was for a long time an adequate description of the role of some typical lubricants. The realization that stearic acid can have a stabilizing effect, when used with some of the more recent stabilizers, and not in other systems, has complicated the evaluation problem. The lubricant, which has largely been regarded as a maintenance item, is often not measured out as meticulously as is the stabilizer. When used in the proper concentration for optimum stabilization it may have almost no lubricant effect.

This, then is another potential pitfall which the stabilizer evaluator must consider.

Lubricants are not inert; lubricant addition must be considered in the choice of the stabilizer.

Conclusion

These pitfalls are illustrative of the widespread problem of changing and refining test methods to meet new situations. Only by careful and patient analysis of each step in the evaluation process can the wise choice be made, which will result in superior quality and reduced cost.

The stabilizer manufacturers can and do contribute much to this program in their own technical service work. The consumers of stabilizers help themselves as they place greater emphasis on precision in testing, and as they maintain their continuous awareness of factors affecting stabilizer evaluation.

As industrial experience has repeatedly shown that clearer thinking not only makes for better stabilizers; it also makes for better choice of available stabilizers, and, therefore, for better vinyls for the buying public.

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Fabricating Silicone Laminates to Get the Most Strength

The most important factor in determining the strength of low-pressure silicone laminates at both high and low temperatures is the completeness of cure. Other fabricating variables analyzed as to their effect on laminate strength include: manufacturing source of the glass fabric, number of plies in the laminate, catalyst concentration, resin pickup, precure time, precure temperature, press temperature, laminating pressure and time, and postcure time and temperature.

L.W. Breed
Howard Christie
Calvin Bolze
Fred Baiocchi
Midwest Research Institute

A KNOWLEDGE of the dependence of the strength properties of laminates on the fabrication variables is particularly important in experimental work where laminate strength is used as a criterion of resin quality. A study has been made in this laboratory of the importance of laminating parameters in determining strength of silicone-glass fabric laminates. In these experiments a group of laminates was prepared under various conditions from a commercial low pressure silicone laminating resin and a heat-cleaned 181 style glass cloth. These laminates were tested for ultimate flexural strength, and the results of the experiment were analyzed by statistical methods.

This research was supported in whole or in part by the United States Air Force under Contract No. AF 33(616)-3675, monitored by the Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

Variables studied were those involving the composition of the laminate, the impregnation and precure steps, the laminating procedure, and the postcure conditions. Changing the magnitude of any particular variable was evaluated directly for its effect on the strength of the finished laminate, rather than for its effect on a secondary property of the system, such as gel time or percent flow.

The statistically designed experiment was used because, first, it allows the selection of those laminating variables whose effects are important as determined by a designated confidence; second, it peermits an evaluation of nonadditive relations (interactions) between variables. Additionally, it allows the partial replication of experiments—a procedure by which results may be obtained without running all possible combinations of the variables. A final advantage is that the error in-

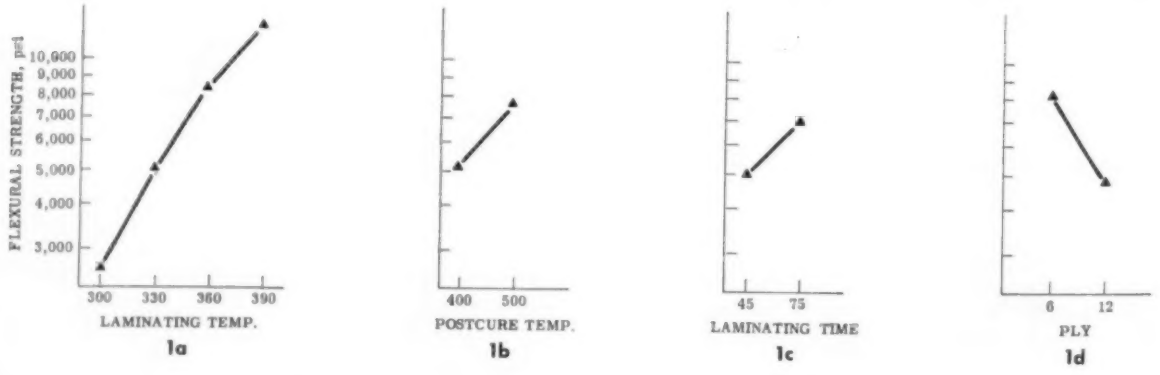

Figure 1. Main effects—Combined room temperature and 500°F flexural strengths.

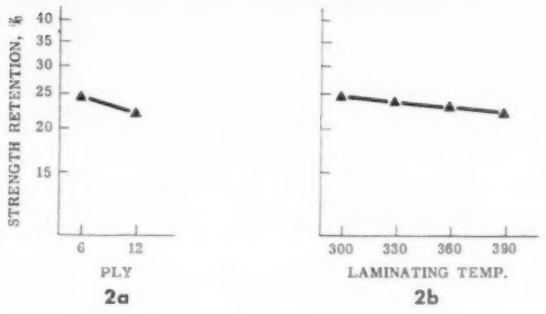

Figure 2. Main effects—Strength retention at 500°F.

volved in preparing and testing the laminates may be accurately assessed.

EXPERIMENTAL DESIGN AND ANALYSIS

Variables and the levels of each selected for study are shown in Table I. In many cases these levels were selected to straddle the value recommended by the manufacturer. The experiment called for the preparation of 128 laminates and the design was a 1/32 replicate of a $2^9 \times 4^2$ factorial. The order in which these laminates were prepared and evaluated with respect to the variables was randomized.

Calculations for the statistical analysis were carried out on a National Cash Register digital computer. Numerical results, expressed in several ways, are included in the accompanying tables and figures and represent the following different methods of treating the data:

Determining Strength and Strength Retention

The average ultimate flexural strengths at room temperature and 500°F are shown in Table II for each level of the variables studied. Where the difference in strength between the levels was significant or approached significance, an appropriate symbol is used. These values represent "main effects" or the contribution of a particular level of a variable to strength independently, i.e., when the effects of all other variables are balanced.

Corrections were made in the analysis for the deviation in resin pickup which resulted from the hand-dipping technique. It was found that these corrections did not materially change the "main effects" for the experiment as a whole.

Further statistical analysis was applied to the logarithms of the flexural strengths. This transformation was chosen for two reasons. First, the variation in test strength increased with mean test strength and the log transformation introduced a weighing factor to compensate for this trend. In addition, the log model was more appropriate because the effects of the variables were more multiplicative than additive.

Each variable was tested for its effects on mean strength and strength retention. The first value is equal to $1/2(\log \text{strength}_{RT} + \log \text{strength}_{500°F})$, and the test reflected the effect of the variable studied on laminate strength in general. The second value is equal to $(\log \text{strength}_{500°F} - \log \text{strength}_{RT})$ and indicated whether the variable's effect was independent of test temperature.

In the figures, "main effects" revealed by mean strengths are shown in Figs. 1a, 1b, 1c, and 1d; "main effects" indicated in strength retention data are given in Figs. 2a and 2b. The variables between which interactions occurred are shown in Figs. 3 and 4. In Figs. 3a, 3b, 3c, 3d and 3e, these nonadditive effects are represented by mean strengths; in Figs. 4a, 4b, 4c, 4d, 4e, 4f, 4g and 4h, interactions are represented in terms of laminate strength retained at 500°F.

TABLE I

Laminating Variables and Levels Studied

Variable	Levels
1. Fabric	Manufacturer A
	Manufacturer B
2. Laminate thickness	6 ply
	12 ply
3. Catalyst concentration	17% < recommended by manufacturer
	17% > recommended by manufacturer
4. Resin pickup	38%
	45%
5. Precure time	4 min.
	7 min.
6. Precure temperature	210°F
	240°F
7. Laminating temperature	300°F
	330°F
	360°F
	390°F
8. Laminating pressure	10 psi
	20 psi
	30 psi
	40 psi
9. Laminating time	45 min.
	75 min.
10. Aftercure time (at final temperature)	24 hr.
	48 hr.
11. Aftercure temperature (final temperature)	400°F
	500°F

Determining Resin Content

Table III shows the average resin content corresponding to each level where the variable was significant in determining resin content.

SUMMARY OF RESULTS

On the basis of the analysis of the experiment, a number of generalizations were made. These generalizations, treated in detail in the discussion section, are summarized as follows:

1. In general, completeness of cure was the most important factor in determining over-all laminate strength Optimum conditions for each of the cure steps—precure, lamination and postcure—were interdependent. Press

temperature during lamination was the most important single variable. At the recommended temperature (347°F), nonadditive relationships with other variables were at a minimum; however, better strengths appear to be possible at higher press temperatures. Longer lamination periods always gave stronger laminates. Increasing postcure time and temperature significantly increased both low and high temperature flexural strengths.

2. Variables important in determining gel time of the resin and resin flow during lamination were not important in determining strength.

3. Increased resin flow appeared to contribute significantly to the strength retention of laminates when tested at 500°F.

4. Variables which were significant in determining resin content were not significant in determining laminate strength.

5. Increasing the number of plies in a laminate decreased the ultimate flexural strength in pounds per square inch.

6. Manufacturing source of glass fabric did not appear to affect the strength significantly, but certain uncontrolled variables did not permit a proper assessment of this effect.

7. At the 95% confidence level, a 25% difference in strength was required to make the difference between two laminates statistically significant.

DISCUSSION AND CONCLUSIONS

It should be noted that the values shown in Table II are average strengths for all laminates that represent a particular level of any variable. The low numerical magnitude of these values reflects the fact that certain combinations gave very poor laminates. Use of appropriate conditions allowed the preparation of laminates from the commercial laminating resin having a strength exceeding 40,000 and 16,000 psi at room temperature and 500°F, respectively.

Cure Variables

Completeness of cure was the most important factor in determining over-all laminate strength. Significant "main effects" which determined combined low- and high-temperature laminate strengths were found in the laminating temperature, postcure temperature and press time—all cure variables—and the best strength was invariably associated with the highest level of each variable.

Polymerization of the fluid resins is advanced in three distinct stages. Stage I (precure) is carried out at moderate temperatures (210-240°F) for short times; stage II (lamination) is carried out between (300-390°F) under pressure; stage III is carried out at higher temperature, up to 500°F for 1 or 2 days.

These three stages are not independent insofar as the strength retention of the finished laminate is concerned. Figure 4d illustrates that the optimum cure temperature for stage II depended on how far the polymerization was advanced (as determined by precure time) in stage I. In Fig 4c, it is evident that the best temperature for stage III depends on the temperature in stage II, although, in general, a 500°F postcure was preferred. Thus, for a laminate to have the best possible strength retention, it was necessary that the cure conditions selected for any stage be chosen on the basis of the cure conditions for the previous polymerization stages. Even though only the laminating temperature was independently significant, the nonadditive nature of the relationship of laminating temperature with the other cure variables with regard to the strength of the laminates is statistically significant.

Press temperature was shown in the analysis of the experiment for "main effects" to be the most important variable within the limits of the level studied. The im-

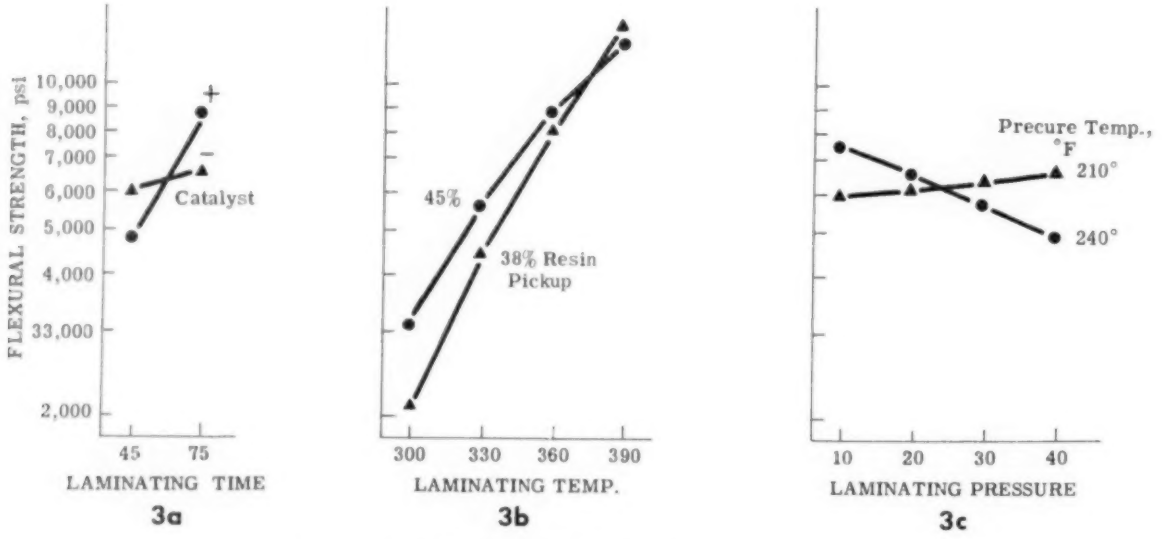

Figure 3. Significant interactions—Combined room temperature and 500°F flexural strengths.

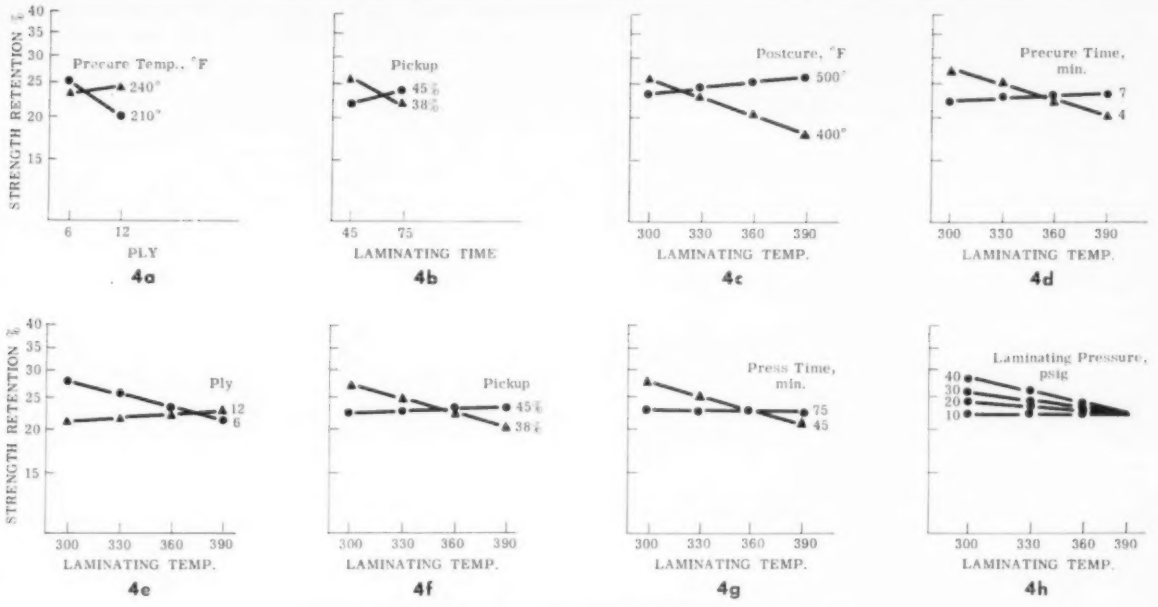

Figure 4. Significant interactions—Strength retention at 500°F.

provement in laminate strength at both high and low temperatures by increasing the laminating temperature through the range studied in the experiment—300, 330, 360, 390°—was shown to be significant, suggesting that 347°F (manufacturers' recommendation) may not necessarily be the best press temperature. A possible explanation for the acceptance of 347°F as the optimum laminating temperature may be found on examining the numerous interactions that occurred between press temperature and the other variables. It will be noted that the null point between each of the curves in Figs. 3b, 4c, d, e, f and g lies between 320°F and 370°F. If 347°F were used as a press temperature, importance of nonadditive effects with the other variables would be minimized. Minor changes in the various steps in preparing a laminate would lead to fewer erratic results.

Contrary to the opinion that improved high-temperature performance in the flexural test may be obtained at the expense of low-temperature performance by increasing the postcure temperature, such a treatment served to improve both (See Table II).

Flow and Gel Time

Variables which are critical in determining such characteristics of the resin system as gel time and flow did not significantly affect the flexural strength of the finished laminate independently either at room temperature or 500°F.

Within the limits of the experiment, no significant effects were found when the levels of the following variables were changed independently: catalyst concentration between 17% below and 17% above that recommended by the manufacturer; precure temperature between 210° and 240°F, and laminating pressure between 10 and 40 psi. The three factors which appeared to be most important when the mean flexural strengths were considered were laminating temperature, postcure temperature, and laminating time. None of the later variables concern the precure and impregnation steps which are effective in altering the gel time and resin flow of a laminate.

The strength retention of laminates appeared to be closely related to variables which determine resin flow. For example, in Figs. 4e and 4f, the deleterious effect of higher laminating temperatures on strength retention is marked for the thinner laminates obtained either from a lower resin pickup or fewer plies, but by increasing the number of plies or the resin pickup, the effect of increased press temperature on strength retention became small. If a thermal gradient across the thickness of the laminates during lamination can be assumed, the resin in the center of the thicker laminate would be expected to remain plastic for a longer time. In thinner laminates, gelation can occur so rapidly throughout the entire laminate at higher temperatures that insufficient flow is obtained to give good strength retention. For thicker laminates, insulation of the outer layers permitted at least part of the resin flow regardless of the laminating temperature. Figure 4g shows that the effect of laminating temperature on strength retention was large for a shorter laminating time, yet when the press time was extended, strength retention became independent of laminating temperature. Because of the plasticity of the resin, even when past its gel point, long laminating periods allowed sufficient resin flow to make strength retention independent of laminating temperature.

A similar line of reasoning may be used to explain the interaction between laminating temperature and pressure in Fig. 4h. Greater pressures brought about increased resin flow and simultaneously better strength retention. As the laminating temperature was increased, thereby shortening the gel time and consequently the resin flow, the changes in strength retention resulting

from differences in laminating pressure leveled off. At 390°F press temperature, strength retention was independent of laminating pressure.

Increased laminating temperature caused a small decrease in strength retention, probably by shortening the gel time and decreasing the resin flow. Press temperature was the most important factor in determining over-all laminate strength; the loss in strength retention which can be attributed to decreased flow is small in comparison with the over-all gain in strength at higher laminating temperatures.

Resin Content

An analysis of the data with regard to resin content of the laminates indicated that precure time and laminating pressure were the only two factors other than fabric which were significant in determining resin content. The relation of resin content to these two variables is easily explained on the basis of flow. Neither of these factors which were significant in determining resin content was significant in determining strength, however. This does not imply that resin content is not an important variable, since the experiment was not designed to include it as one of the variables.

Resin pickup approached significance in determining laminate strength at room temperature, but resin pickup was not a significant factor in determining resin content. When resin pickup is considered independently, the effects of the other variables would be expected to be balanced, and a direct relationship exists between resin pickup and resin content. These results probably developed from the fact that the two levels of resin pickup selected were not sufficiently separated to allow significant differences in the results. However, it does suggest that resin pickup in a series of laminates might be varied over a fairly large range, and by the proper adjustment of resin flow with precure conditions and laminating pressure, laminates might be obtained having the same resin content. The strength of these laminates could be directly related to the resin pickup in spite of the fact that resin content does not change.

Error

From the experimental data, an error term was calculated to determine the normal variation that may be expected when a laminate is prepared and tested. This indicated that for two values of average flexural strength to be significantly different (95% confidence level), it was necessary that the values show a difference of about 25%. This error factor reflects the uncertainty in comparing strength values of two individually prepared laminates whose strengths do not differ by a large amount.

PREPARATION AND TESTING OF LAMINATES

Impregnation

In the experiment, all laminates were prepared from a heat-cleaned 181 style glass cloth supplied by two manufacturers and a commercially available low-pressure silicone laminating resin. The resin was catalyzed at the level indicated in the experimental design, either 17% more or 17% less than the amount of catalyst recommended by the manufacturer for the particular lot of resin. If the resin pickup was to be 45%, the resin, which contained 60% dissolved solids, was diluted 5% by weight with toluene; if the resin pickup was to be 38%, the resin solution was diluted 15% with toluene. Glass cloth strips were hand-dipped in the resin solution, then allowed to dry for 30 min. in moving air at room temperature. These impregnated strips were precured in a circulating air oven for a period of time (4 or 7 min.) and temperature (210° or 240°F) specified by the experimental design, and, after the strips were precured, they were cut into 10-in. by 10-in. sheets.

Lamination

Layups, weighed and wrapped in amber cellophane, were laminated at the time (45 or 75 min.), temperature (300°, 330°, 360° or 390°F), and pressure (10, 20, 30, or 40 psi) specified in the experimental design. Press closure cycle was held constant for all laminates. The press was closed in 20 sec. to the desired pressure, the pressure released for 5 sec., and the press again closed allowing 10 sec. to reach the final pressure. At the conclusion of the laminating period, the platens were cooled to 200°F and the laminate removed. The cellophane release film was stripped from the laminate, excess flash material removed, and the laminate weighed. Resin pickup during impregnation, resin flow during lamination, and the resin content of the laminate were calculated from the weight of glass fabric used and the weight of the laminate before and after pressing.

Postcure Cycles

The laminates were placed in an oven at room temperature and brought to the final postcure temperature. These cycles are as follows:

For 400°F Final Temperature
2 hr. at 300°F followed by
2 hr. at 350°F followed by
6 hr. at 375°F followed by
24 or 48 hr. at 400°F

For 500°F Final Temperature
2 hr. at 300°F followed by
6 hr. at 425°F followed by
24 hr. or 48 hr. at 500°F

At the end of the postcure period, the oven was turned off and allowed to cool to 200°F before the laminates were removed.

Testing

The laminates prepared were tested in accordance with Federal Specification L-P-406b Method 1031-1 for ultimate flexural strength at room temperature and 500°F. Ultimate strengths were determined using a Baldwin-Southward Universal Testing Machine with a Dillon Mechanical Pressure Gage. (0-500 lb. range—1% scale accuracy) mounted on the loading nose shaft of the testing machine.

★ ★ ★

Pinpoint Important Process Variable with POLYVARIABLE EXPERIMENTATION

Here's a simple, nonmathematical statistical system for determining the controlling variables in an operation. Whether you are trouble-shooting or trying to find optimum process conditions, polyvariable experimentation can save time and money where many variables are involved.

F.E. Satterthwaite
Statistical Engineering Institute
D. Shainin
Rath and Strong, Inc.

SINCE 1956, several progressive engineering and research groups have been gaining experience with polyvariable experimentation; that is, experimentation in a large number of variables—10, 20, and more. Theory predicts that for complex investigations such experimentation is many times more efficient than classical few-variable experimentation. Experience to date has borne out these theoretically predicted gains.

Why the emphasis on experimentation in many variables? The answer is that in appropriate situations it does a better job with respect to the factors that are of controlling importance:

(a) **Information return.** Theory and experience show that the information acquired per dollar invested in experimentation tends to increase at least linearly with the number of variables investigated.

(b) **Cost.** Polyvariable experimentation is, in general, substantially less expensive, than an equally thorough investigation using classical few-variable experiments.

(c) **Risk of inadequate answers.** Unless most variables that may be important are investigated, the risk of an inadequate answer is serious.

(d) **Administration.** Polyvariable methods are flexible. They readily adapt to the administration, operating, and physical limitations that complicate any major investigation.

(e) **Time.** When time is important you must investigate all questions in parallel. This is in fact many-variable experimentation. It is best to plan such investigations by polyvariable theory. Classical few-variable experimentation is not adequate.

Most of us have on occasion sat in on planning committee meetings for experimental investigations, perhaps with ten experts sitting around the table. Each expert is invited because he has personal knowledge that may be important to solution of the problem at hand. Each expert contributes perhaps five factors that his special knowledge indicates may be important to the solution. The committee secretary now has a list of possibly 50 factors that should be studied. However, it is practical to experiment on only five factors. Which five? Somehow they must be selected.

Eventually the problem is solved. Was the key to the problem one of the five factors selected in the committee meeting? Was it one of the 45 factors suggested but not investigated? Was it some factor that did not even come up in the committee meeting? Experience includes all three results. But has the percentage of successful results with the five selected by the committee been a tolerable success rate for the pace of today's research and engineering activity?

Experience suggests that the planning committee method for selected the few important variables is not good enough, even when carried through with the greatest skill. However, there is an effective alternative —experimentation in many variables, 10, 20, even 100.

This article is based on a paper presented at the Conference on Application of Statistics to Experimentation, sponsored by Northeastern Section of American Chemical Society.

The deliberate (as opposed to accidental) use of polyvariable experimentation in engineering and industry is recent. To date much of this experience has been with a single technique, random balance. Most of this experience has involved "intuitional" steps in the analysis that may perhaps be disturbing to the scientific and mathematically inclined. But the point at issue is, "Does it Work? At least on certain classes of problems?"

An Example of Random Balance Experimentation

Successful experience with random balance experimentation, intelligently applied to a problem in plastics manufacturing, is reported by Spencer Chemical Company's sales service laboratory. They were called upon to solve a specification problem for a company that was extruding plastics pipe. The critical specification in this case was burst strength. Seven variables were considered to have a possible effect on this characteristic: feed screw speed, feed screw temperature, plastic melt temperature, water bath temperature, sizing mandred, draw ratio and effect of reworked material.

The first step in programing the experiment was to set up a table with each variable heading a column. In this case, 27 was thought to be a sufficient number of tests because of the relatively small number of variables. The experiment was further simplified by choosing to test each variable at only three levels: high, medium and low. Values chosen were typical of the firm's usual operations.

The randomization entered in the establishment of the value of each variable for each test run. Although more elaborate randomization methods could have been used, an easy one was to place 27 consecutively numbered slips of paper in a hat and draw them out one at a time.

The first nine numbers drawn were used to designate the test numbers for which each of the variables (e.g., feed screw speed) would be set at a high reading. Medium readings were assigned to runs corresponding to the next set of nine numbers drawn at random; the nine numbers left in the hat were for low readings. The process was repeated for each of the six other variables, and a full program filled out (thus, in this particular case, 189 draws determined the conditions for all 27 tests).

The next step was simply to run the 27 tests right in the plant under the randomly selected conditions prescribed. The burst strength of the pipe produced in each run was measured and plotted in charts, showing the effect of each of the seven variables (two of which are shown in Fig. 1).

The "effect curve" for draw ratio—connecting the mean values of each column—had a strong upward slope, indicating a correlation between this variable and burst strength. The data for the other variables (e.g., feed screw speed) showed little or no correlation.

The final step, was to set tolerances on the important variables to keep burst strength within specifications. This was done after 95% confidence limits—determined by regular statistical methods—were added to the charts. In this case, the specification for minimum pipe burst strength was 300 psi on 95% of the product. The draw ratio that will insure this percentage of good pipe was found (see Fig. 1) at the intersection of the lower confidence limit and the 300-psi line.

Similarly, a maximum tolerance could be set (at 350 psi, for example) by using the upper confidence limit. Tolerances for other major variables were set in the same way.

"This case history taken from the article "Simple System Spotlights Vital Variables" in the March 22, 1958 issue of *Chemical Week*.

Figure 1. Graphs show variables' effects, point to best conditions.

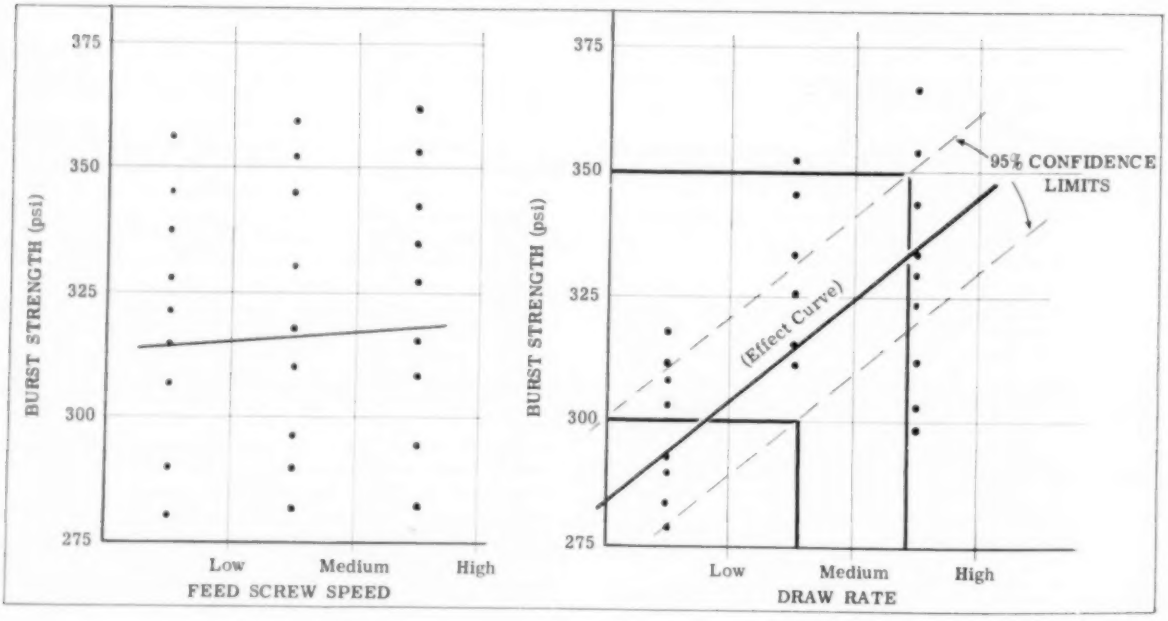

TABLE I

Random Balance Experiment

Test No.	Feed Screw Speed	Feed Screw Temp.	Melt Temp.	Water Bath Temp.	Sizing Mandrel	Draw Ratio	Effect of Reworking
1	H	L	L	M	H	L	H
2	M	H	M	H	L	H	M
3	H	L	L	M	L	H	M
4	L	M	H	H	H	M	L
5	M	H	L	L	M	L	H
6	M	M	M	L	H	M	M
7	H	M	M	L	H	L	M
8	H	H	L	H	L	M	H
9	L	L	H	L	M	M	L
27	M	M	L	H	L	M	H

An Example of Polyvariable Experimentation

For a "do-it-yourself" demonstration of the technique, the data in Table II are presented. These were obtained from 28 experiments in 18 variables. Each line of Table I is the data set for a single experiment. Thus the first line is an experiment with variable number I set at level 2, variable number 2 set at level D, variable number 3 set at level 33, etc. The output yield of the resulting experiment was 89% as shown in the last column. The second line is a separate experiment with an output yield of 85%.

These are raw data. The only manipulation has been to arrange them in order of the output result, a yield. *The problem is to identify the input variable which it is most important to control if consistently large yields are to be obtained.* To test whether you can do this without further guidance, study Table II *now*. (If you read further before you make this test, you will not be sure that you could have solved this problem without help.)

You undoubtedly spotted variable number 8, a catalyst. Every experiment using a catalyst A gives a higher yield than any experiment using catalysts B or C. The average yield for catalyst A is about 81%, for catalysts B and C about 69%. What is a percentage point improvement in yield worth? $10,000 per year? $100,000 per year? This is 12% improvement with catalyst A may be worth substantial money. It is clearly the most significant information in these data. (Note: The true advantage of catalyst A is a 10% yield improvement. The effect of other factors misled us by 2%.)

There is a second obvious conclusion to be drawn: note the experiment with the highest yield, 89%. Remember our problem, "What combination of variables should we use to obtain the highest yield?" Can we be far off if we use the combination that did in fact give this highest yield? This may not be the best combination but it cannot be far off. (Note: This is in fact a "best" combination. The true average yield for the combination is 87.5%. The unexplained variation has misled us by 1.5%.)

This second conclusion is a worthwhile improvement over the first. The true average yield for the first conclusion is 79.5%. The second conclusion is 8% better, in some situations conceivably worth $80,000 per year more.

There is, of course, more information in these data than the obvious conclusions. The statistician with experience in polyvariable analysis will show convincingly that variable 12, a temperature, has an important effect. How? Suppose the 18 experiments using catalysts B and C had in fact used catalyst A. Their yields would have been about 12% greater. Making this adjustment to the data, we obtain the plot in Fig. 1. This graphically shows that the best temperature is near 80°, the extreme temperatures, 60° and 90°, should be avoided. The true relation for temperature variable 12 using catalyst A is in fact:

Temperature	60°	65°	70°	75°	80°	85°	90°
Average Yield	75	77	80	83	85	80	75

The statistician would probably also suspect that variable 16, a purity, has a real effect (it does). There would probably be two or three other variables about which he would be equally suspicious (but no other variables have any effect).

His important conclusion, however, would be that about a ±5% yield variation is due to causes other than variable 8, catalyst, and variable 12, temperature. He would also state that about half the undefined variation is due to variables not identified in the present data. To determine reliably the causes of this residual varia-

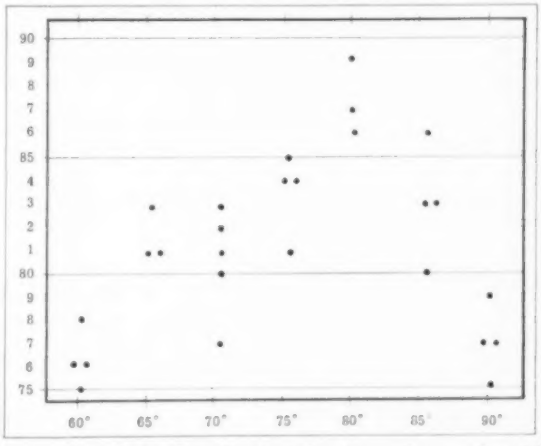

Figure 2. Relationship showing the dependence of yield on temperature variable (12).

tion additional data would be necessary, including additional variables. The present data do, of course, give much information for planning the additional experiments so that they will give the greatest possible information return.

Randomization

You say that things cannot be this simple, that you have been fooled by data just as obvious as these. This is correct. However, it should be remembered that this set of 28 experiments was planned in a special way. The choice of each variable value for each experiment was taken from a table of random numbers. Of course the effect of one variable confuses the interpretation of another variable. But unlike the confusion introduced by arbitrary relationships among variables, the confusion introduced by random relationships is mathematically defined and strictly limited. With 28 experiments the confusion averages out, so that the remaining confusion is not serious. The risk of an important misinterpretation is small.

Conduct Your Own Polyvariable Experiment

The acid test, of course, is to try polyvariable experimentation on a real problem in your own operations. This will no longer be playing games with synthetic data. It will be real data that costs real dollars. You will be looking for useful new knowledge that will return those dollars to you with substantial profit.

Appendix A outlines the rules for a trial random balance experiment. These are over-simplified and will in many applications be inadequate. Experience has shown that they are relatively safe for well administered experiments and will usually make the important results obvious.

Strict attention must be paid to instruction A, "Selection of the Problem." You will still be playing games with unimportant data unless the potential savings are worthwhile. Do not let the experiment bog down from administrative headaches. There must be at least 10 variables easily controlled at values you specify. You will not want to wait a year for results. Be sure at least 30 data sets can be collected in about two weeks. Follow up to be sure you get them within the specified time. Do not spend a lot of money. This is only an exploratory study. You may have to sacrifice some variables you think important to meet these requirements. Do so. The important point is to include a lot of variables obtained relatively easily and inexpensively. If you include enough allegedly "unimportant" variables, something interesting and valuable is very likely to turn up. Remember that no one has bothered to study the "unimportant" variables before.

Why Polyvariable Experimentation Works

Polyvariable experimentation greatly increases the odds that the information necessary to solve your problem will actually exist in the data. If a factor is held constant in the experiments, the data contain zero information regarding the effect of varying that factor. If a factor held constant is in fact important to the solution, the experiments will surely fail to solve the problem. If you only knew the few factors most important to the solution, you would have no trouble, but you usually cannot know what are the important factors to investigate. A real problem of long standing is almost certain to be solved by a factor (variable) that is alleged to be unimportant. The factors thought to be important will have been investigated one or more times before with negative results.

If you accept the premise that the solution may be a factor (variable) that appears unimportant, you are forced to a polyvariable approach. Let us assure a list of 50 such "unimportant" factors with no reliable information to choose among them. A single variable experiment has a 2% chance of including the right variable. A five variable experiment has only a 10% chance of including the right variable. A 25 variable experiment has a 50% chance of including the right variable. The only way to improve your odds is to include more "unimportant" variables.

In practice the odds against you are often much more serious than the above. Most problems have one most important variable and spotting this is almost always a help. Generally, there are a few variables (one to five) which are necessary to understand for a satisfactory solution. We must spot a specific combination of two or more variables to solve the problem well.

Let us assume the solution lies in a specific combination of only two variables from among 50 possible variables. You have no chance of getting the answer if only one variable is investigated. If only two variables are investigated, you have one chance in 1225 that the correct two will be selected the first time. For even odds for a successful experiment you must investigate 35 out of the 50 possible variables.

For a complex problem whose solution requires finding the right combination of three variables, what percentage of the candidate variables must be included in the experiment for 50-50 odds of success? The center column of Table II gives the answer—79%. If you need the right combination of 10 variables, you must experiment in 93.3% of the candidate variables. Table II also gives the percentages of the candidate variables that you must include for a 25% chance of success and for a 75% chance.

Elementary Applications

Much of the experience to date with polyvariable experimentation has been in the areas of inexpensive data and very simple (usually graphical) analysis methods. These areas have been dominated by trouble-shooting, process optimization, and tolerance optimization problems, with the data collected on the factory floor. "Scattershot" laboratory investigations have also been quite successful. An example of this is the development of an adhesive by a large user who wanted to make his own. Many formulations resulted which were superior in performance *and* lower in cost. "Unimportant" variables did, of course, turn out to be important. The experience of Spencer Chemical Company is typical of most of the experience to date.

In this type of application (inexpensive data, simple analysis), there are almost no technical problems to the widespread use of polyvariable experiments of the random balance type. Technical personnel do, however, generally underestimate the psychological, educational, and administrative problems. They may be completely frustrated by the inertia, the unwillingness to change, the million and one excuses as to why the operation cannot be done. If rapid progress is to be

made, it is almost necessary that the program be under the full time direction of an industrial or management engineer who makes a profession of the art of making things work when human beings are a key factor.

Advanced Applications

The pressure has been building up, primarily from and within large research organizations, for sophisticated use of polyvariable methods with expensive data, with electronic computation, and in fundamental research. A recent request was for the study of 14 variables with only 10 data sets where the experimentation would cost over $1,000,000 and take three years to complete. The methods outlined in Appendix A are not sufficiently efficient or objective for such investigations.

This pressure has caused a number of individuals to study the fundamental mathematical problems of polyvariable analysis. The first public presentation of results was at the 1958 annual meeting of the Institute of Mathematical Statistics, which had a session of invited papers on these problems.

A paper by Professor J. Kiefer (Annals of Mathematical Statistics, September 1958) entitled "On the Nonrandomized Optimality and Randomized Nonoptimality of Symmetrical Designs" is of great mathematical significance. Professor Kiefer shows that random designs can always be found which are more efficient than the classical fixed designs such as full factorials, Latin squares, etc.

Mathematical progress is encouraging. The classical statistical principles for analysis of few variable data have been found to generalize to polyvariable data without loss of optimum properties. (This extension of multiple regression analysis is called polygression analysis.) The bigression analysis technique discussed in the present paper has many computational advantages and is ideally suited to optimum utilization of pertinent and reliable prior information. (Polyvariable investigations can quickly become so complex that computational problems cannot be ignored even with large scale computors.) Quadratic estimation of parameters (as opposed to *linear* regression estimates) is a completely new attack on the problem of "best" (most precise and accurate) estimates. Empirical (Monte Carlo) studies indicate that quadratic estimates are probably almost always better (and often substantially better) than the "best" classical linear estimates. The reasons why this should be so are only beginning to be understood.

These more advanced methods of polyvariable analysis are not limited to experiments planned by the random balance principle. They are applicable to unplanned data and to experimental data planned by any of the classical design principles: factorial, fractional factorial, response surface, etc.

If your ogranization is sufficiently large, your investigations sufficiently complex, and your projects sufficiently important, you should consider getting started in these advanced polyvariable methods as soon as possible. In any case, electronic computation cannot be used except incidentally without the advanced methods. The computor does not think and cannot use methods such as outlined in Appendix A.

TABLE II

Sample Polyvariable Data

28 data sets. 18 input variables. One output yield.
Data sets arranged in order of output yield.

Input Variable Number

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Yield
2	D	33	2	C	5	17	A	70	H	L	80	35	B	7	99	2	C	89
9	B	32	2	D	3	10	A	90	L	M	75	30	D	5	99	1	A	85
5	D	34	6	D	9	10	A	80	L	M	75	50	C	5	97	3	D	84
4	B	34	1	F	7	13	A	70	L	M	85	30	C	8	97	9	C	83
8	A	31	4	B	3	18	A	80	H	H	70	35	C	1	99	5	C	82
6	C	30	5	E	9	10	A	90	H	H	75	40	B	9	90	8	B	81
7	D	33	2	E	5	14	A	80	L	H	70	30	A	7	90	9	D	80
3	A	34	1	A	7	14	A	60	L	L	90	35	C	3	99	5	D	77
5	C	31	3	C	6	15	A	80	H	L	70	50	B	6	90	7	C	77
2	D	35	2	F	7	14	A	90	L	H	60	45	C	9	95	8	C	76
5	D	35	2	A	4	16	B	80	L	H	80	45	D	1	90	2	A	75
2	C	35	1	E	4	18	C	70	L	L	80	50	D	5	93	6	C	74
3	A	34	3	D	6	12	C	90	H	M	85	40	B	4	98	2	C	74
9	B	33	2	A	1	12	B	90	L	M	75	30	A	7	90	6	B	72
6	D	31	6	D	4	14	B	80	H	H	85	30	C	9	99	5	D	71
7	A	30	2	D	7	12	C	70	L	H	70	55	A	1	98	7	A	71
4	B	33	4	B	5	18	B	70	L	L	65	30	D	1	99	7	B	71
9	C	31	6	E	4	15	B	90	H	L	80	50	A	4	90	8	D	71
8	A	33	5	A	4	16	C	60	H	M	65	45	D	2	98	0	A	69
5	D	31	5	C	7	11	C	60	L	H	65	45	D	9	97	1	C	69
6	C	31	1	F	3	19	C	70	H	H	70	50	B	5	95	8	B	69
4	B	32	4	F	5	10	B	50	H	M	85	45	A	1	97	7	B	68
4	C	35	3	C	7	15	B	50	H	H	90	50	C	3	98	3	A	67
3	C	30	4	A	9	15	C	90	L	L	60	35	C	7	93	2	C	66
3	B	35	3	B	1	15	B	60	H	H	90	55	A	7	93	4	B	65
7	B	35	3	C	2	13	C	90	H	L	60	45	D	6	95	1	B	64
9	A	30	4	A	9	17	B	80	L	M	60	55	B	6	95	1	A	63
5	D	34	1	A	1	10	C	80	H	H	90	35	B	8	93	9	D	63

APPENDIX A

Rules for Trial Random Balance Experiment

A. Select the Problem for Random Balance Trial.

(1) Potential savings worthwhile.
(2) At least 10 variables under your control.
(3) At least 30 data sets can be obtained quickly at nominal cost.

B. Design the Experiment.

(1) List variables.
(2) Select at least three values for each variable: H = high value, M = medium value, L = low value.
(3) The difference between the H and L values should be at least five times the measurement error for that variable.
(4) For each data set (i.e., each experiment), select H, M, or L values for each variable independently at random. (See Exhibit D for a Random Number Table and an example showing how to use it.)

C. Run the Experiments.

(1) Omit any experiments that have impossible (impractical) variable combinations.
(2) Record one or more response variables (yield, purity, strength, etc.) for each experiment.

(3) Up to five exact duplicate experiments are often desirable. These measure your experimental ability to reproduce results exactly. (The five duplicates should be selected at random from the total list and run at random times.)

D. Analyze the Results.

(1) Arrange the data in order with respect to each response as in Table I. (Make a separate table for each response variable.)

(2) Examine this table for any non-random patterns of the input variables.

(3) Plot, as in Fig. 1, the response against input for any variables that *appear* non-random in (2).

(4) Interpret the physical and economic significance of any plots that give sharp indications of real effects.

(5) Pay particular attention to the one or few experiments with the best output results.

(6) Trust only obvious interpretations unless you have guidance from a statistician experienced in random balance analysis.

E. Confirm the Interpretations.

(1) Important interpretations may be confirmed by additional experiments using classical few variable experimental designs.

(2a) Additional information, as well as confirmation, will be obtained by a second random balance design.

(2b) Variables with clear effects in the first analysis should be held near their best values.

(2c) Variables with no apparent effect in the first analysis should, if practical, be varied over a wider range (up to double the range is conservative).

(2d) Run extra experiments at the input variable values which gave the best responses in the first analysis. Run fewer (but not zero) experiments at the input variable values which gave poor responses in the first analysis.

(2e) Include additional variables that may be practical at this time. This is particularly important if your exact duplicate experiments did not give good reproduction of the responses. There is then an important variable unidentified in the first set of experiments.

★ ★ ★

TABLE III

Odds that Selection Includes Right Variables:

Number of variables that must be selected correctly	1 in 3	Even	3 to 1
	Percentage of candidate variables that must be included in the experiment (number of candidates large)		
1	25 %	57 %	75 %
2	50	71	87
3	68	79	90.8
4	71	84	93.0
5	76	87	94.4
7	82	90.5	96.0
10	87	93.3	97.2
20	93.3	96.6	98.6
30	95.4	97.7	99.04
50	97.2	98.6	99.42

APPENDIX B

Random Numbers

	1–4	*5–8*	*9–12*	*13–16*	*17–20*	*21–24*	*25–28*	*29–32*	*33–36*	*37–40*
1	80 99	42 43	08 58	54 41	98 05	54 39	34 42	97 47	38 35	02 19
2	48 83	64 99	86 94	48 78	79 20	62 23	56 45	92 65	56 36	34 11
3	28 45	35 85	22 20	13 01	73 96	70 05	84 50	68 59	96 58	73 52
4	52 07	63 15	82 30	66 23	14 26	66 61	17 80	41 97	40 27	27 97
5	39 14	52 18	35 87	48 55	48 81	03 11	26 99	03 80	08 86	50 57
6	37 56	19 18	03 42	86 03	85 74	44 81	86 45	71 16	13 52	35 56
7	64 86	66 31	55 04	88 40	10 30	84 38	06 13	58 83	62 04	63 52
8	22 69	58 45	49 23	09 81	98 84	05 04	75 99	27 70	72 79	32 19
9	23 22	14 22	64 90	10 26	74 23	53 91	27 73	78 19	92 43	68 10
10	42 38	56 64	72 96	46 57	89 67	22 81	94 56	69 84	18 31	06 39
11	17 18	01 34	10 98	37 48	93 86	88 59	69 53	78 86	37 26	85 48
12	39 45	69 53	94 89	58 97	29 33	29 19	50 94	80 57	31 99	38 91
13	43 18	11 42	56 19	48 44	45 02	84 29	01 78	65 77	76 84	88 85
14	59 44	06 45	68 55	16 65	66 13	38 00	95 76	50 67	67 65	18 83
15	01 50	34 32	38 00	37 57	47 82	66 59	19 50	87 14	35 59	79 47
16	79 14	60 35	47 95	90 71	31 03	85 37	38 70	34 16	64 55	66 49
17	01 56	63 68	80 26	14 97	23 88	59 22	82 39	70 83	48 34	46 48
18	25 76	18 71	29 25	15 51	92 96	01 01	28 18	03 35	11 10	27 84
19	23 52	10 83	45 06	49 85	35 45	84 08	81 13	52 57	21 23	67 02
20	91 64	08 64	25 74	16 10	97 31	10 27	24 48	89 06	42 81	29 10
21	70 58	28 49	54 32	97 70	27 81	64 69	28 99	39 63	32 03	71 91
22	09 68	96 10	57 78	85 00	89 81	98 30	03 67	30 54	86 04	12 41
23	19 36	60 85	35 04	12 87	83 88	66 54	39 71	24 10	62 22	21 53
24	04 75	44 49	64 26	51 46	80 50	53 91	00 91	28 80	40 23	09 91
25	79 83	32 39	46 77	56 83	42 21	60 03	18 57	05 79	20 09	31 46

Example. It is desired to distribute 4 A's, 7 B's, 5 C's at random to experiments numbered from 1 to 16. First, pick at starting point in the random number table at random. Such a starting point might be: row 11, column 29-30. Number = 78.
Next read two digit numbers in any direction. If, for example, we read to the right, we have

78, 86, 37, 26, 85, 48, 39, 45, 69, ...

In reading these numbers write down the first four numbers between 01 and 16. These are 11, 02, 01, 06. The four A's should be assigned to the four experiments with these numbers:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	A				A					A					

Continuing to read the random number table the next seven numbers between 01 and 16 are: 16, 13, (01), 14, (14), 03, (16), (01), (14), 15, (01), (01), (03), (11), 10, (10), (06), 08.
(Duplicates, of course, are skipped.) The seven B's are assigned to the experiments with these numbers:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	A	B			A		B		B	A		B	B	B	B

The five C's are now, of course, assigned to the remaining 5 experiments.

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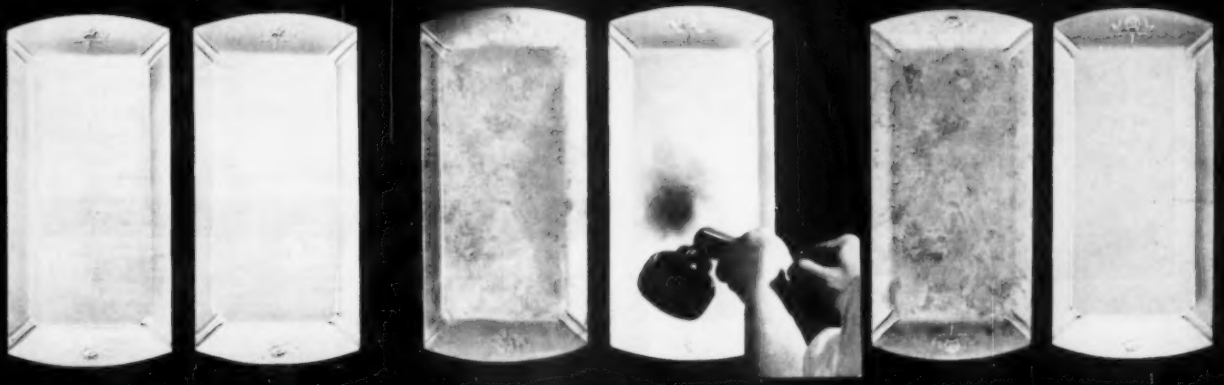

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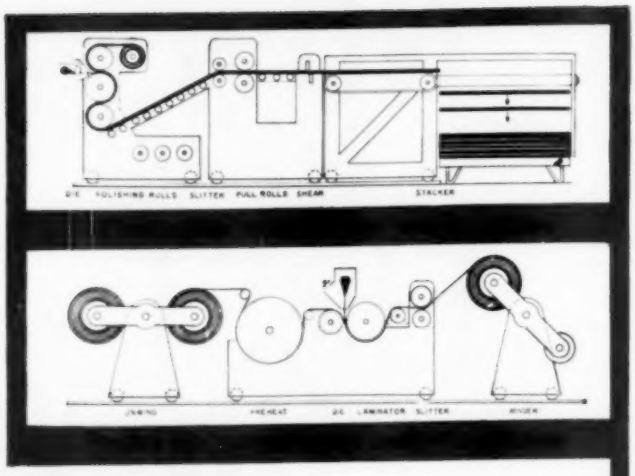

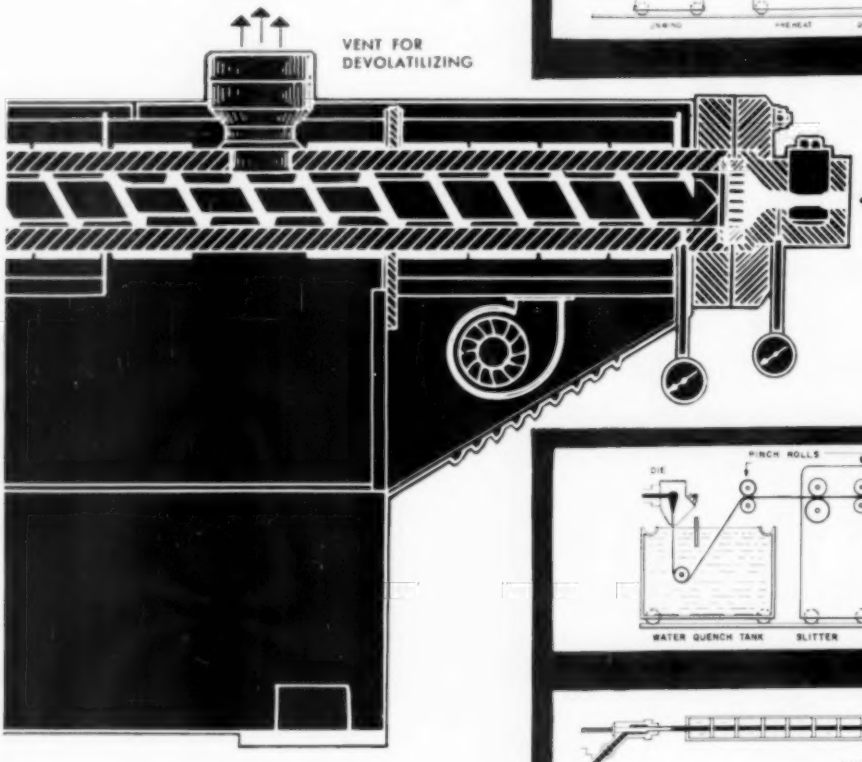

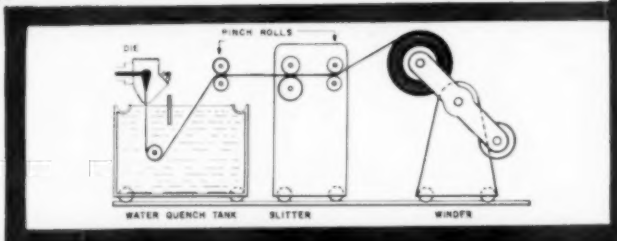

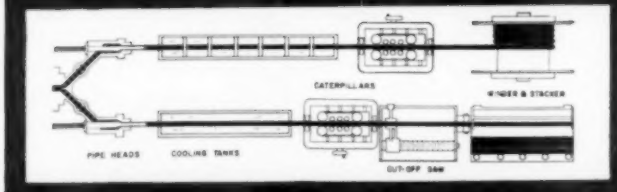

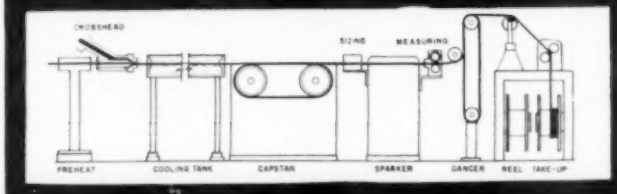

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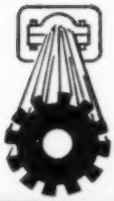

Edited by B. H. Maddock
Union Carbide Plastics Co.

SPEAKING of EXTRUSION

Extrusion of Polyethylene Film with Controlled Properties

W.A. Haine and H.B. Robinson
Union Carbide Plastics Co.
Development Department

THE QUALITY or usefulness of a product can be enhanced or reduced depending on the degree of consideration given to each phase of its manufacture. Thus, to adequately define the quality of a product, it is necessary to trace its history from the raw material stage to the finished application. A polyethylene film package, for example, exists as a result of purified raw materials being changed into a resin; a converter extruding this resin into film; the possible printing of this film; and finally the fabrication of the printed film into a bag. The care and technology injected into each of these steps represents a direct measure of the ultimate quality and usefulness of the packaging unit. And, the more thoroughly the factors affecting these production stages are investigated and optimum conditions applied, the better will be the specific characteristics of the final product. With these thoughts in mind Union Carbide Plastics Co. has investigated several important extrusion variables that affect the properties of polyethylene film produced by the flat film extrusion process. The results of these studies form the basis of this paper.

As new fields of application for polyethylene film arrive on the scene, the physical, optical, or permeability properties required for one application may differ from the specifications for film to be used in another application. For example, the best optical properties are sought for film that is to be used for the packaging of retail goods. On the other hand, strength properties are of paramount importance when the film is to be used for heavy duty applications such as industrial container liners or agricultural applications. One method of fulfilling a customer's need for particular film properties is to engineer such specifications into the film. This can be accomplished by utilizing the inherent resin properties in conjunction with the proper fabricating (extrusion) conditions.

Changes in extrusion conditions produce corresponding changes in the film. However, these variable conditions can be controlled, and with the proper combination of controlled conditions, a film of optimum clarity may be produced. A different set of controlled conditions may be used to produce a film with optimum strength characteristics.

This paper discusses some of the extrusion variables, and their effects and inter-relationship, from the standpoint of producing flat polyethylene film with controlled properties. For instance, how would an increase in compound temperature affect the strength properties of extruded film? Or, what would be the dual effect on extruded film if the compound temperature were reduced and the extrusion rate increased? The answers to these and similar questions will be made apparent by the subsequent discussion.

Variables Studied

The fabrication of polyethylene film by extrusion consists of forcing molten resin through an orifice, drawing the resin sufficiently to yield a film of desired thickness, and then cooling it. While sounding very simple, this process is actually a highly complex, non-linear, rheological system. It involves the fundamental resin properties of molecular weight and molecular weight distribution, and the physical factors of stress, strain, time, and temperature, which are present during the drawing operation. Here, we are mainly concerned with these physical factors, or extrusion variables, which affect the rheological behavior of the resin during its formation into film. The extrusion variables investigated were those of compound temperature, film speed (or extrusion rate), draw distance (die lips to water), and water bath temperature. (See Fig. 1). Testing was performed over the following variable ranges:

1. *Compound Temperature*: 215°C and 230°C.
2. *Film Speed*: 60, 80, and 120 fpm.
3. *Draw Distance*: 1″, 2″, 3″, and 4″.
4. *Water Bath Temperature*: 40°, 50°, 60°, and 70°C.

Two polyethylene materials were employed, both resins having a melt index in the range of 1.7-2.4 and a density of 0.92. The extruder conditions listed in Table I were used to provide the desired compound temperatures and extrusion rates. It should be noted that both compound temperatures were measured at a screw speed of 28 rpm by wrapping molten polyethylene around the bulb of a thermometer. It is expected that the actual temperatures at 18 rpm and 42 rpm with the same barrel and die control settings would differ slightly due to the variation in dwell time of the resin in the extruder. This simplification may have altered the actual numerical values of the data.

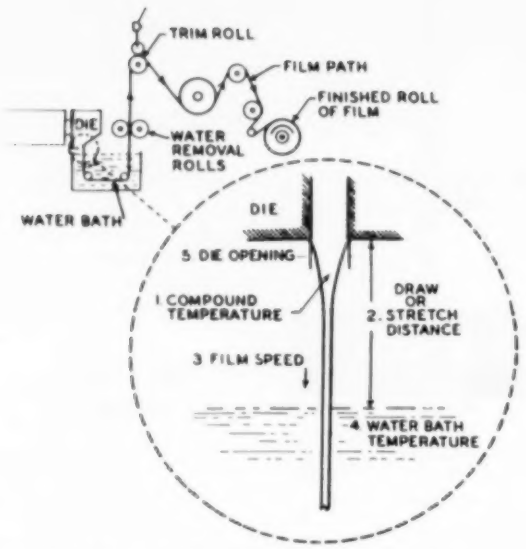

Figure 1. Schematic diagram of the flat film process.

Optical Properties

Compound Temperature — Film haze decreases and gloss increases when the compound temperature is changed from 215°C to 230°C (see Figs. 2 and 3). The effect on optical properties of varying the compound temperature within this range is relatively minor. As the temperature level is reduced the change in clarity for a given temperature change increases. Also, the better the optical quality of the resin, the less will be the over-all effect of compound temperature.

Film Speed—Haze increases and gloss decreases with increasing film speeds, if a constant draw distance is maintained (see Figs. 2 and 3).

Draw Distance—Haze decreases with increasing draw distance until a minimum (which varies with film speed) is reached. Then, haze may increase 1% to 2% due to the slower air cooling that has started prior to the entrance of the film into the water bath (see Figs. 2 and 3). These Figures also show that film gloss increases with increasing draw distance.

Water Bath Temperature—The water bath temperature has no appreciable effect on film by haze or gloss when varied from 40°C to 70°C (see Fig. 4)

Mechanical Properties

Compound Temperature—Raising the compound temperature appears to be the best means of improving the strength properties of film made at high extrusion rates. Compound temperature increases give results similar to those realized by increasing the stretch distance at constant temperature, consequently, the stretch distance must be reduced to maintain constant film properties. The distance for optimum impact strength is also reduced (see Figs. 5 and 8).

Film Speed—Tensile strength increases as film speed is increased. Constant elongation may be maintained at increased film speeds by a corresponding increase in draw distance (see Fig. 9).

Draw Distance—At constant film speed, tensile strength decreases with increasing draw distance (see Fig. 9). Elongation increases with draw distance until a maximum is reached (varies with film speed), after which it may decrease (see Fig. 9). Constant tensile strength and elongation can be maintained at increasing draw distances as film speed is also increased (see Fig. 9). The impact strength of a film is a function of tensile strength, elongation, and apparent modulus Since both the tensile strength and the elongation change with draw distance, there is an optimum combination that produces the maximum impact strength (see Figs. 5 and 8). Adequate performance requirements appear to be 3,000 psi in the machine direction and approximately 350% elongation.

Water Bath Temperature—Tensile strength decreases with increasing bath temperature. On the other hand, elongation passes through a minimum and then increases with increasing bath temperature. The location of this minimum point is affected by film speed (see Fig. 7). The impact strength is generally improved by reducing the bath temperature (see Fig. 6).

Discussion of Results

This detailed evaluation of the effect of extrusion variables on film

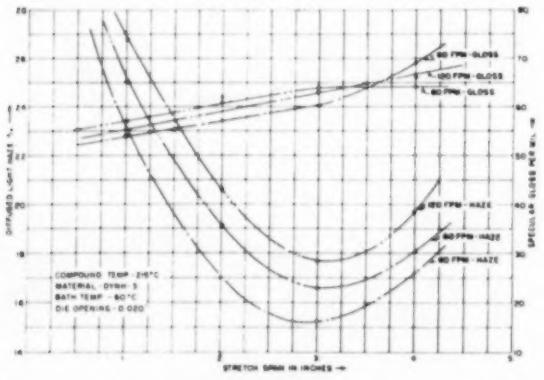

Figure 2. Effect of stretch distance on optical properties.

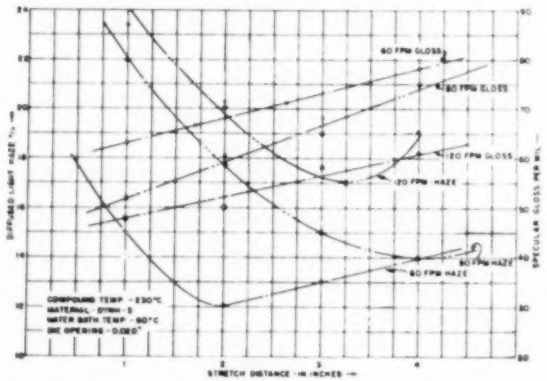

Figure 3. Effect of stretch distance on optical properties.

properties shows that compound temperature, film speed, draw distance, and water bath temperature are very closely related. The selection of the proper combination of extrusion conditions based on these four variables will yield a flat film with controlled impact strength or clarity.

The film tensile properties of 3,000 psi (machine direction), 350% elongation (machine direction), and low apparent modulus appear to be essential for the production of a high impact strength flat film. Due to effect on the apparent tensile modulus of the film, the elongation in the machine direction is very important. A reduction in the residual elongation of the film raises the apparent modulus, and this has a detrimental effect on the impact strength. Conceivably, carried to extremes, this increase in apparent modulus due to orientation could overcome the beneficial effects of a low resin density. Flat film having a bag drop strength in excess of ten feet has been produced under the optimum extrusion conditions reported herein.

From the standpoint of film clarity, draw distance is the most sensitive extrusion condition. Compound temperature, film speed, and water bath temperature are secondary variables with a reduced

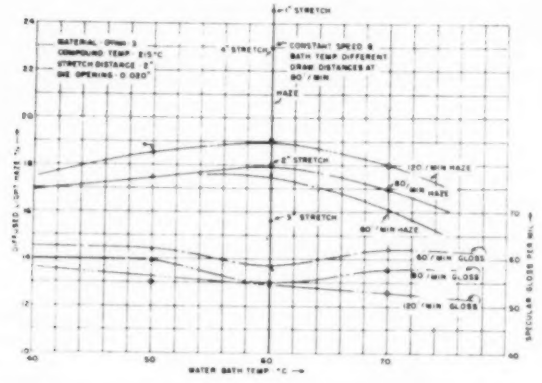

Figure 4. Effect of water bath temperature on optical properties.

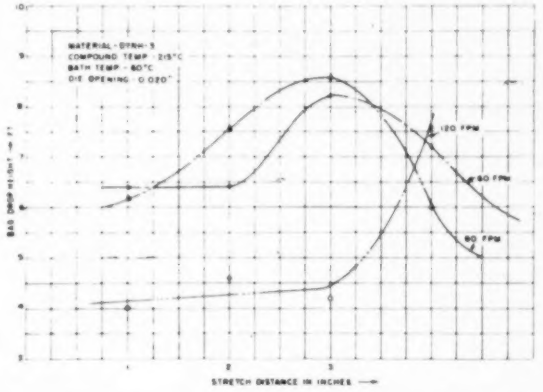

Figure 5. Effect of stretch distance on bag drop height.

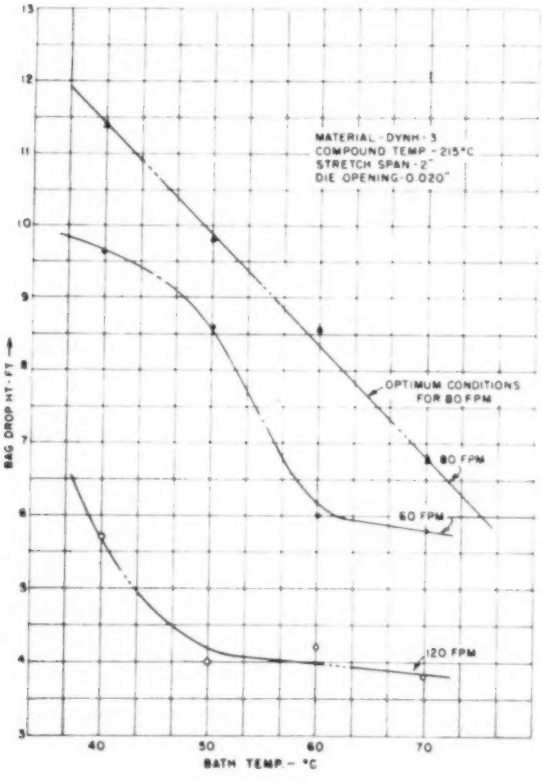

Figure 6. Effect of water bath temperature on bag drop height.

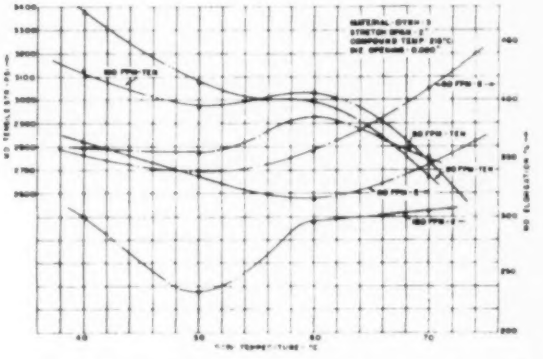

Figure 7. Effect of water bath temperature on film tensile properties.

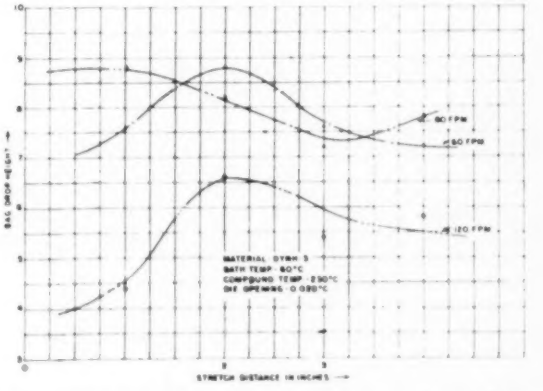

Figure 8. Effect of stretch distance on bag drop height.

effect on clarity over the range of conditions tested. This concept differs somewhat from the presently accepted idea that the water bath temperature is the most effective variable relating to film clarity. The effect of all extrusion variables on clarity is also greatly affected by the clarity characteristics of the base resin. For example, the lower the haze level of the resin, the less will be the effect of the extrusion conditions on that resin.

A critical examination of the trends indicated in this film data raises the question of the desirability of high linear film speeds for quality film production. As the film speeds increase, the extrusion conditions that are necessary to produce high quality film rapidly diverge from those which are desirable for good economical extrusion operation. There are also limitations to the amount of change that can be made in some of the extrusion variables to compensate for the increased speed. For example, long stretch distances caused heavy end beads which cannot be eliminated without causing continual edge tears. Presently, a film speed of 80 feet per minute appears to offer the greatest possibilities for matching optimum extrusion conditions, from the production viewpoint, with those conditions that produce the most desirable commercial film properties.

Actually, the entire area of high film speeds (150 fpm and upward) generally merits special consideration. This is also true of other factors such as the effect of die opening, molecular weight and molecular weight distribution, and basically different polyethylene resins, all of which are outside of the scope of this paper.

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TABLE I
Extruder Conditions

Compound Temperature at 28 rpm, °C		215	230
Screw Inlet Temperature, °C		63	63
Screw Outlet Temperature, °C		77	77
Die Temperatures	Zone 1, °C	240	254
	Zone 2, °C	230	246
	Zone 3, °C	219	235
	Zone 4, °C	232	249
	Zone 5, °C	238	252
Barrel Temperature	Zone 1, °C	149	149
	Zone 2, °C	221	225
	Zone 3, °C	254	274
	Zone 4, °C	254	274
	Head, °C	219	235

Die Opening—Nominal 0.020″, set cold, adjusted to give 1.5 mil film when operating at 28 rpm screw speed and 215°C compound temperature. Screens —20-60-100-20.

Screw Speeds		Output—lbs./hr.
18 rpm	1.5 mil film at 60 fpm	105
28 rpm	1.5 mil film at 80 fpm	165
42 rpm	1.5 mil film at 120 fpm	250

Equipment—4½″ extruder—L/D-20/1—4:1 compression ratio screw—Constant pitch, decreasing depth, with constant depth metering section, fully cored for cooling. Die—60″, 5 zone control.

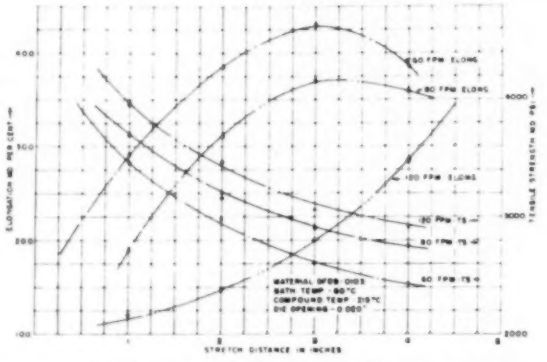

Figure 9. Effect of stretch distance on film tensile properties.

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A grant of $200 is being made by SPE in memory of William H. Dunnican for a one year junior scholarship fund in Plastics Engineering at Lowell Technological Institute, Lowell, Mass.

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Dean of Students Richard W. Ivers suggests that application be made to the Director of Admissions, Lowell Technological Institute, Lowell, Mass.

Mr. Dunnican, in whose honor this scholarship is being made, was an active member of SPE. As a pioneer in the Society he was one of the originators of the SPE Constitution and contributed generously and tirelessly to the Society's cause. In his effort to expand the activities of SPE he helped to form several Sections, and was a Director of the Newark Section at one time.

SPE is proud to contribute toward the furthering of a student's career in plastics engineering. It recognizes the continuing need for these engineers as the increased plastics production has made a steady demand in this industry.

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U.S.I. POLYETHYLENE NEWS

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MARCH, 1959 U.S. Industrial Chemicals Co., Division of National Distillers and Chemical Corporation 99 Park Ave., N. Y. 16, N. Y.

Packaging Notes

New bread-wrap material is a sulphite-base sheet with an inner coating of polyethylene. The outer surface has a high gloss finish coating. The extruded poly inner surface provides an excellent air-moisture barrier. The sheet withstands the relatively high temperatures of wrapping hot bread and reportedly performs well on existing wrapping machinery.

Amber polyethylene containers are now being used to market photographic and other light-sensitive materials, according to a recent announcement. Lightweight, unbreakable and chemically inert, the containers provide light protection but still allow the user to see the level of the contents. Polyethylene's flexibility is said to be another advantage: Air can be removed and oxidation of the contents prevented by squeezing the bottle and replacing the cap to form a vacuum container.

Poly film and poly-coated corrugated board are combined in a new type of package. The packaged item is encased by vacuum-forming in tight fitting film which is bonded to the mounting board. The board is folded along scored lines and inserted into an outer sleeve of corrugated board for shipping. The method is said to be suitable for a wide variety of packaging applications, ranging from costly, fragile industrial parts to volume-marketed consumer products.

A new adhesive for laminating polyethylene to burlap and other fabrics has been developed. It is expected to be helpful to bag makers and shoe manufacturers seeking to laminate polyethylene with a wet adhesive instead of heat sealing. The adhesive is said to be particularly useful in the manufacture of bags used for fertilizer and feeds.

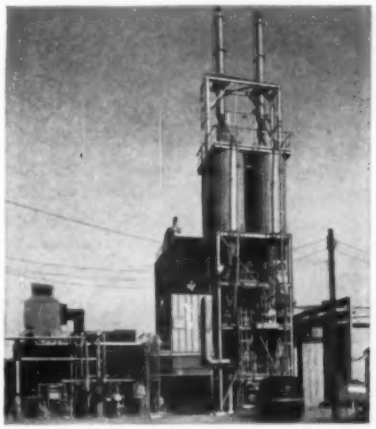
Machine which sets up tuck lid, poly-coated, bleached sulfate boxes and trays reportedly can produce up to 3000 units per hour. The machine heat-seals the box corners on the inside, leaving the exterior smooth and flat. Boxes and trays made by the machine are being used to package frozen foods, bakery products, candy, fresh foods and industrial parts.

A new polyethylene bottle with a rotating sleeve, also of polyethylene, has been designed to solve the problem of labeling. A horizontal channel for the sleeve is molded around the outside of the bottle. A paper label can be inserted in a vertical opening in the sleeve which is then rotated to cover the label. Inside the channel and protected by the sleeve, the label cannot fall off or be damaged by splashing liquids.

U.S.I. Starts Up New Plant at Tuscola For Compounding Petrothene® Resins

To Process 25 Million Lbs. of Resin Per Year

A new plant for compounding polyethylene resins with carbon black and other additives has been opened by U.S.I. at its petrochemical complex at Tuscola, Ill. The plant, which will handle 25 million pounds of resin a year, enables U.S.I. to assure its resin customers of even higher quality control than previously.



U.S.I.'s new polyethylene resin compounding plant at Tuscola, Ill., will handle 25 million pounds of resin a year.

In polyethylene pipe and electrical applications, the care with which carbon black is compounded with the resin has an important effect on the weather resistance of the finished product.

Weather resistance of a polyethylene compound depends on three factors: (1) type and particle size of carbon black; (2) percentage of carbon black in the compound; (3) dispersion of the carbon black in the compound.

Dispersion is particularly important. Tests show that good dispersion will enable polyethylene to withstand 15 to 20 times as much exposure as polyethylene with poorly dispersed carbon black.

At U.S.I.'s new compounding plant, only the finest channel black is employed in compounding the wire and cable grades of PETROTHENE resins. Concentration is set at a point which yields the optimum balance of light screening and other properties. Special processing equipment insures thorough dispersion.

Users of black electrical grade polyethylene can get technical data on PETROTHENE resins expressly formulated for electrical applications by contacting their nearest U.S.I. office.

Booklet Lists U.S.I. Resins For Wire, Cable Industry

U.S.I. has issued a four-page booklet classifying the special physical and electrical properties of PETROTHENE polyethylene resins. The booklet lists resins by application, essential properties, and industry specifications. Copies may be obtained by writing to Editor, U.S.I. Polyethylene News, U.S. Industrial Chemicals Co., 99 Park Avenue, New York 16, N. Y.

U.S.I. To Show Cast Film at Packaging Show

Ultra-clear cast film, printed film and other special packaging films will be featured in U.S.I.'s exhibit at the 28th AMA National Packaging Show in the Chicago International Amphitheatre, April 13-16. A team of technical service engineers will also be on hand at the U.S.I. booth (booth No. 1133-1135) to answer questions on packaging applications of films made from PETROTHENE polyethylene resins.

Injection-Mold Poly Tanks With 31-Gallon Capacity

Polyethylene tanks with a capacity of 31 gallons are now being injection-molded for use as salt storage containers for automatic water softeners. The 100-ounce tanks are believed to be among the largest deep-draft parts ever produced by the injection process.

The poly brine tanks measure 21 inches deep, with a maximum diameter of 21 inches. Designed with a two degree draft, they may be nested for economical shipment and storage. The tanks are molded on a specially modified 200-ounce injection machine which operates on a molding cycle of better than 20 shots per hour. The corrosion-resistant, dent-proof polyethylene tanks replace galvanized steel containers formerly used for this application.

U.S.I.

Vol. IV, No. 2

POLYETHYLENE PROCESSING TIPS

CAST FILM PROCESS GIVES TOP CLARITY FILM

Film extruders seeking greater clarity and gloss should investigate the cast film process. With this technique, you can produce polyethylene film with clarity equal or superior to that of other commonly used transparent packaging materials.

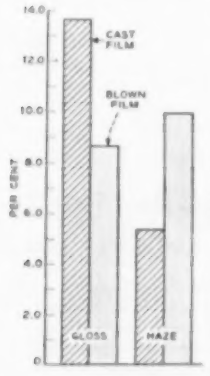
Casting Procedure

Casting involves extruding a molten web of polyethylene on a mirror-finished, water-cooled roll. Either standard flat-film extrusion equipment or conventional extrusion coating equipment can be modified for use with the new process.

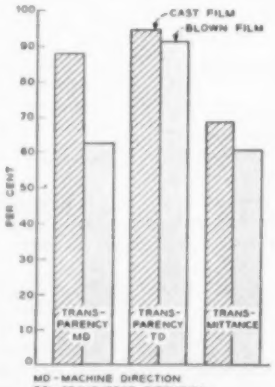
The melt is extruded through a slot die onto chrome-plated chilled rolls where it cools rapidly and solidifies. Under tension maintained by a driven windup roll and guide bars, the film is transferred at controlled speed over idler bars to a razor or score-cut slitter roll. The idler rolls permit further cooling before winding; and in trimming ½" to 1" from the film edges, the slitters remove the bead from the film edge.

Relation Between Properties and Process

Cast film has outstanding optical properties because the process controls the two principal causes of haziness in polyethylene film: surface roughness, which diffuses light passing through the film; and a partly amorphous-partly crystalline resin structure, which results in uneven light diffraction.



Comparison of optical properties (gloss & haze) of cast film vs. blown film (angle of incidence = 60°)



Comparison of optical properties (transparency & transmittance) of cast film vs. blown film

The casting roll surface determines the surface characteristics of the film. Consequently, cast film has as smooth a surface as the highly polished rolls whose contour it follows.

Haze-producing crystals in the matrix of the polyethylene are held to a minimum by keeping the film at high temperature until it hits the chill roll. The more rapid the cooling rate, the fewer the crystals and the smaller the spherulites – and the clearer the film.

Optimum Operating Conditions

Efficient production rates – generally faster than conventional methods – can be achieved by a proper balance of operating variables.

A die setting of 10 to 20 mils is recommended. A lower setting produces higher gloss and a significant reduction in neck-in tendency, but more blocking. Keeping the draw-down distance between the die lip and chill roll to a minimum also reduces neck-in, thereby making it easier to attain uniform gauge.

Excellent gauge control is possible in a range of film widths and in gauges from 0.5 to 4.5 mils. As gauge increases, a reduction in blocking occurs.

As low a stock temperature as possible will give best results for blocking and neck-in properties. Since gloss is impaired at low stock temperatures, the minimum temperature should probably be not less than 400°F.

A uniform "frost line" must be mainfained as the film is cast. This is an indication that the melt is solidifying uniformly, that gauge is uniform, and that there will be no puckering or warping of film. It is achieved by balancing the chill roll temperature with the lineal speed and gauge of the film being extruded.

Sealing characteristics of cast film are not critical in either transverse or machine direction. Transverse-direction seals require a higher sealing temperature.

Choice of Resin

Lower density resins generally can be extruded into films with good optical properties by the cast film technique. It is therefore not necessary to make a large sacrifice of strength for clarity. PETROTHENE® 239 has been found to have the combination of properties most extruders require for such applications as overwrap, bread wrap and soft goods bags.

U.S.I. has pioneered in the cast film process, and is continuing to work in the lab and in the field on improvements in production methods. Our engineers will be glad to assist you in evaluating this new technique in your operations. Contact your nearest U.S.I. office or write:

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spe RETEC *Regional Technical Conference:*

Designers Look at Reinforced Plastics from the Pleasure Boat, Aircraft and Missile Industries Viewpoint

Sponsored by the North Texas Section
Adolphus Hotel, Dallas, Texas
April 28, 1959

8:00 A. M.—REGISTRATION

SESSION I
Aircraft and Missiles

8:45-11:30

Key Note Speaker:
GENERAL PROBLEMS ENCOUNTERED
Dr. Albert G. H. Dietz
Massachusetts Institute of Technology

CHARACTERISTICS AND ANALYSIS OF REINFORCED PLASTICS FOR ELECTRICAL APPLICATIONS
Samuel Oleesky
Zenith Plastics Co.

STRUCTURAL CHARACTERISTICS AND ANALYSIS OF REINFORCED PLASTIC PARTS
R. W. Matlock
Summit Industries

VARIOUS PROCESSES USED IN FABRICATING REINFORCED PLASTIC PARTS
Benjamin Sokol
Republic Aviation Corp.

RESINS AND REINFORCEMENTS FOR USE IN REINFORCED PLASTICS
J. V. Young
Chance Vought Aircraft

12:00 M.—CONFERENCE LUNCHEON

Guest Speaker:
PLASTICS IN RUSSIA
J. E. FitzGerald
Brunswicke-Balke-Collender Co.

SESSION II
Pleasure Boats

2:00 P. M.

Key Note Speaker:
WHY DESIGN QUALITY INTO REINFORCED PLASTIC BOATS?
Clint Haig
Libby-Owens-Ford

INDUSTRIAL DESIGNER LOOKS AT REINFORCED PLASTICS
Fred M. Gore
Industrial Design

DESIGN INFLUENCES ON ENGINEERING REINFORCED FIBERGLASS BOATS
Dow Moore
Ferro Corp.

A MARKET MAN LOOKS AT DESIGN
Tony Cobb
Owens Corning Fiberglas Co.

For more information write to Chairman William McConnell, Air Accessories, Inc., 1400 Henderson St., Ft. Worth, Texas.

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Capacity 75 to 100 lbs. Each Drum

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Specifications same as Model T-2 except that 1 HP motor is supplied in place of ¾ HP.

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Takes drums up to 43" high and in all diameters up to 24".

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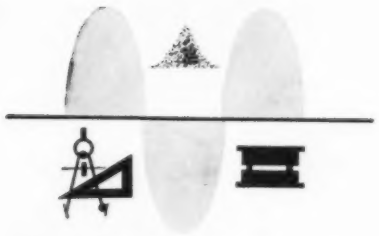

Edited by Louis Paggi, *Consultant*
E. I. du Pont de Nemours & Co., Inc.

MOLDING CYCLES

Induction Heating for Injection Molding Machines

Winchel J. Goodwin
Hale and Kullgren, Inc.

ASK AN ENGINEER or plant superintendent if he has any problems with the heating cylinders on his injection molding machines and you are very likely to hear quite a tale of woe. Complaints such as "wish I could hold temperatures more closely," "have to replace heaters too often," "heating contactors beat themselves to pieces," "takes too long to heat-up," "workers complain of heat from machine," and "wish I could reduce my power bills," will be in this tale.

Tests recently completed at Amos Molded Plastics Co. indicate that induction heating of these cylinders will do much to eliminate many of these complaints. A standard, late model, 24-ounce Watson-Stillman machine was selected for installation of the induction heating units. The heating cylinder was originally equipped with tubular heaters installed in grooves. In addition, two band heaters were connected to the front zone. Total heater capacity was 24.4 kilowatts arranged in three zones of approximately equal length.

The above heating elements were replaced with three induction heating assemblies of equal length designed for operation at either 220 or 440 volts, 60 cycles. Each assembly consists of two 220-volt coils, 1" of thermal insulation ($k = 0.57$ BTU/sq. ft./in./°F at 600°F), a magnetic structure and mounting parts. Each assembly was designed for 5 kw with coil taps to permit adjustment of power input above and below this value.

To establish a basis for comparison of performance of induction heating with resistance heating, data were obtained from an identical resistance heated machine which was producing a similar product. The power consumption, operating temperatures, and production were recorded over a four-day period. These data, along with that from the induction heated machine are summarized in Tables I and II. Both machines were processing Monsanto #HT88 Styrene.

Now, what advantages does induction heating offer over resistance heating? On the basis of these first tests, the following is evident:

1. Electric energy is used much more efficiently due to the use of thermal insulation around the cylinder. This will result in a significant reduction in annual power cost.
2. Precision temperature control is for the first time possible without the use of complicated and expensive control systems. Since the heat is generated directly in the cylinder wall there are no thermal lags resulting in deviations from control set point (overshoot or undershoot). Standard "off-on" type controllers without proportioning control action will provide more accurate control of temperature than is possible with any other heater-controller combination presently used on injection molding machines.
3. The surface temperatures of the heating elements are considerably lower—increasing operator comfort and reducing the burn hazard present with other heaters. Due to the low operating temperature of the coils, high temperature wire and terminals are not required.
4. Since the operating temperatures of the coils are well within safe limits, they should have extremely long life. With the use of NEMA Class H insulating materials and coil construction methods, a life of 10 to 20 years is not beyond reason.

TABLE I
Power Input

Machine	Shot Wgt oz.	Rate Shots/hr.	Prod. lbs./hr.	Heater Cap.—kw Front	Center	Rear	Watt-Hours Per Pound	System Efficiency
No. 27—Induction Ht'd.	14.6	76	69.3	5.8[a]	4.8	6.0	40.6	80%[b]
No. 28—Resistance Ht'd.	14.9	75	69.8	8.4	6.4	9.6	96.9	34%

[a] Includes 1.5 kw Band Heater.
[b] Calculated from previous laboratory work.

TABLE II

Heater Performance

Machine	Control Set Point Front	Center	Rear	Deviation From Set Point	Maximum Heater Surface Temp.
	°F	°F	°F	°F	°F
No. 27—Induction Ht'd.	500	530	530	None[a]	170° and 200°[c]
No. 28—Resistance Ht'd.	494[b]	579[b]	573[b]	±5° to 10° cylic	1000° to 1200°[d]

[a] Only observable pointer movement was that required to initiate control action.
[b] Average of control set points used over four-day period.
[c] The 200°F temperature was experienced on the coils for the rear zone only. This is due to coils operating at 3.0 kw each rather than at or below the 2.5 kw value for which they were designed. A tap for producing design kw was not available on these coils.
[d] Estimated. Temperatures beyond the 800°F range of the surface pyrometer.

5. A major maintenance problem presently lies with the contactors controlling the power to the heaters. These contactors are frequently subjected to very severe cycling due principally, to the proportioning control action required of the controllers when used with resistance heating. With induction heating, this cycling is greatly reduced since proportioning type control action is neither required nor even desirable. Thus, contactor maintenance will be greatly reduced.

Now, there must be some drawback to induction heating. The principal one is that of first cost. At the present state of the art, the cost of the heating units is from three to four times that of resistance heating. However, when all factors are considered, including reduced maintenance, downtime and scrap production, as well as reduced operating cost, the extra expenditure will be justified. Since these heaters operate at around 65% to 70% power factor, (about the same as an induction motor operating at 1/2 to 2/3 load), the addition of static capacitors may, in rare instances, be required to avoid a penalty billing from the power company.

Departing from the realm of fact and gazing into the crystal ball, we believe that other advantages of this heating method will become apparent. Among these we believe is the likelihood that the precision temperature control possible with induction heating will permit economical processing of materials which have a narrow temperature range at which they can be molded. We also believe that this heating method will permit changes in injection molding cylinder design to achieve higher plasticizing rates. Perhaps lower stock exit temperatures can be used, thus shortening up the cure time in the molds permitting higher production rates.

The Amos Molded Plastics Company is continuing their experimental work with the unit they have. Perhaps these experiments will prove some of the preceding conjectures.

We are particularly grateful to Art Evans, Plant Engineer, of the above company for his cooperation in obtaining the data presented herein.

★ ★ ★

Here is Your Answer to Molding Questions

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Sales Service Laboratory
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Wilmington 98, Delaware

Edited by Thomas A. Bissell
SPE Executive Secretary

NATIONAL ACTION

President's Message
SPE GOALS FOR 1959

OUR SOCIETY has mushroomed from modest beginnings in 1942 to the present membership of 6,500 plastic engineers throughout 27 countries, with an annual budget of almost $300,000. This dynamic growth was directed, planned and put into effect by volunteer members who have willingly and gladly given their time and paid their own expenses to accelerate this growth. Surely we deserve to have tremendous pride in our organization.

SPE's past is only useful insofar as it will help us to plan the future. Accordingly, here are our major goals for 1959:

1. Professional Activities Groups (Frank W. Reynolds, Administrator)
   a. Complete the organization of the authorized Professional Activities Groups; firmly establish the aims and goals of each; and set out to accomplish them.
   b. Establish those Technical Committees requested by members of the Society to study or to recommend standards and/or specifications within the plastics industry.
2. Education and Inter-Society Relations (Jules W. Lindau, III, Administrator)
   a. Implement the recommendations of the Education Committee on both a national and local scale. Assist Sections in starting active educational programs in conjunction with high schools and universities.
   b. Complete program for establishment of a Boy Scout badge in plastics.
   c. Strengthen our program of inter-society relations both on a national and local level. Establish active participation by SPE in the American Standards Association.
3. Meetings (John Delmonte, Administrator)
   a. Establish a program by which we can coordinate papers given on both a national and local level and, at the same time, give greater assistance to the Speaker's Committee of the Annual Technical Conference.
   b. Greater assistance to the 1960 Annual Technical Conference in Chicago by our National Office.
   c. Increase the number and the attendance of Regional Technical Conferences.
4. Publications (Frank A. Martin, Administrator)
   a. Increase our activities for solicitation of papers for the Journal.
   b. Increase reporting on SPE activities in the Journal.
   c. Study desirability of establishing an abstracting service.
   d. Increase advertising so that we can publish an average Journal of 100 pages.
   e. Increase Journal circulation to 9,500.
   f. Reduce printing and operating costs.
   g. Appoint technical editor and authors for "Processing of Thermosetting Materials" and "Design of Plastic Parts."
   h. Review J. H. DuBois and Wayne I. Pribble's "Plastic Mold Engineering" to determine whether it should be brought up-to-date and republished.
5. Administrative Functions (H. S. Nathan, Administrator)
   a. Prepare 1959-1960 budget.
   b. Upon adoption of revised Constitution, publish a complete booklet containing revised Constitution and By-Laws.
   c. Hold election of next National Officers in October in accordance with new Constitution, thus enabling the new 1960 Officers to get their committees established and ready to start by January, 1960.
   d. Study and put into effect a strong publicity and public relations program that will establish SPE in its rightful place among the recognized technical societies of the world.
6. Sections and Membership (George W. Martin, Administrator)
   a. Increase membership to 8,000 members.
   b. Complete Audit Bureau Circulation analysis of our membership.
   c. Rewrite the Section Procedures Manual.
   d. Establish five new Sections on the North American Continent.
   e. As provided by the new Constitution, activate student membership and provide a program for starting 6 Student Chapters.
7. Ad-Hoc Committees
   National Councilmen's travel (Richard A. Jenkins, Chairman)
   a. Study the problem of cost of travel of National Councilmen to quarterly meetings and recommend solution.
   b. Plastics Institute Committee (Ralph L. Mondano, Chairman) Continue study made over the past 2 years on how SPE can be of service to the Plastics Industry through a research program.
8. National Office (Thomas A. Bissell, Executive Secretary)
   a. Complete recommendations and plans and put into effect a more streamlined method of communication between the National Office and Sections.
   b. Study office procedures and mechanics in line with anticipated growth over next three years.
9. Past-Presidents' Advisory Board (Peter W. Simmons, Chairman)
   a. Study and recommend policies for SPE awards and prizes.
   b. Prepare history of Society.

This program can be put into effect and carried out only if we have the assistance of all members. If you are not now active in either local or national work and can give a few minutes of your time to SPE activities, please get in touch with one of your local or national officers and advise them of your ability to work. Remember, when you serve SPE, you serve yourself!

With your support, 1959 can be still another "greatest" year in SPE's history.

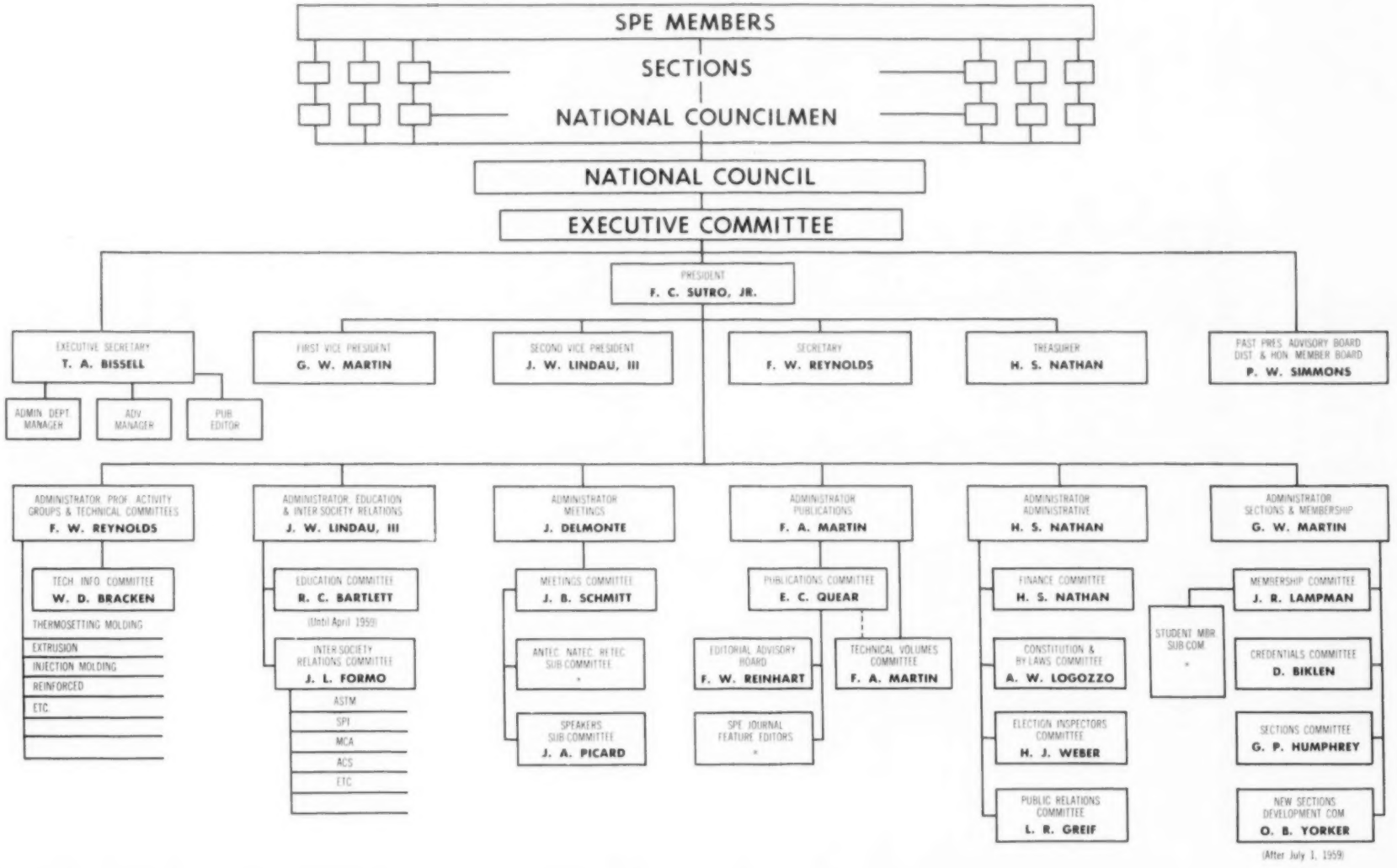
Respectfully submitted,

Frederick C. Sutro, Jr.
National President

SPE ORGANIZATION CHART

WITH THE 1959 NATIONAL ORGANIZATION

(Adopted by Council January 26, 1959 as Appendage to By-Laws)



1959 NATIONAL ROSTER

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(To be appointed)

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ASTM Committee D-20 on Plastics
Kenneth A. Kaufmann (Kansas City)

Building Research Institute
Jerome L. Formo (Upper Midwest)

Forest Products Research Society
(To be appointed)

Institute of the Aeronautical Sciences
(To be appointed)

Institute of Radio Engineers
Ralph L. Mondano (Eastern New England)

Instrument Society of America
Frank A. Martin (Akron)

International Standards Organization
Norman A. Skow (Philadelphia)

Manufacturing Chemists' Association
George W. Flanagan (Baltimore-Washington)

National Conference on the Application of Electrical Insulation
Max M. Lee (Northern Indiana)

National Electrical Manufacturers Association
T. Walter Noble (Milwaukee)

National Society of Corrosion Engineers
Raymond S. Perkins (Non-Section)

Society of Automotive Engineers
(To be appointed)

Society of Motion Picture & TV Engineers
Herbert Meyer (Southern California)

Society of Photographic Scientists & Engineers
Herbert Meyer (Southern California)

Society of the Plastics Industry, Inc.
James R. Davidson (Detroit)

Technical Association of the Pulp & Paper Industry
(To be appointed)

AD HOC COMMITTEES

Councilmen's Travel
R. A. Jenkins (North Texas)

Plastics Institute
R. L. Mondano (Eastern New England)

MEETINGS

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John Delmonte (Southern California)

Chairman
Joseph B. Schmitt (Pittsburgh)

Standing Sub-Committees

Speakers
John A. Picard (Detroit)

1960 Annual Technical Conference
Frank L. Fine (Chicago)

PUBLICATIONS

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Frank A. Martin (Akron)

Publications Committee
Eugene C. Quear (Central Indiana)

Technical Volumes Committee
Frank A. Martin (Akron)

Editorial Advisory Board
Frank W. Reinhart (Baltimore-Washington)

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Finance
Haiman S. Nathan (Buffalo)

Constitution and By-Laws
Arthur W. Logozzo (Western New England)

Election Inspectors
Herbert J. Weber (New York)

Public Relations
Lucien R. Greif (New York)

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George W. Martin (Western New England)

Membership
James R. Lampman (Central New York)

Student Membership Sub-Committee
John M. Berutich (Kentuckiana)

Regional Membership
New England—Sid Lohman (Southeastern New England)
Iroquois—M. Malone (Quebec)
Mid-Atlantic—Samuel H. Greenwood (Philadelphia)
East Central—Sherman M. Crawford (Cleveland)
South Central—John N. Scott, Jr. (Kansas City)
Great Lakes—C. W. Armstrong (Northern Indiana)
Western—(To be appointed)

Credentials
Donald W. Biklen (Newark)

Sections
G. P. Humphrey (New York)

New Sections Development
Oscar B. Yorker (Rocky Mountain) (After July 1, 1959)

Lindau to Head SPE Delegation to European Plastics Conventions

President Frederick C. Sutro, Jr., has appointed 2nd Vice President Jules W. Lindau III as Chairman of an official delegation to represent SPE at two European plastics meetings:

1. The International (formerly British) Plastics Exhibition and Convention Olympia, London, England, June 17-27, 1959, (Sponsored by British Plastics magazine with the support of British Plastics Federation).

2. The Plastics Exposition to be held in conjunction with the Fifth Salon Internationale de la Chimie, Paris, France, June 18-29, 1959.

SPE members who are planning to attend one or both of these conventions are invited to join the SPE delegation. If interested, please communicate with Chairman Lindau, % Southern Plastics Co., 408 Pendleton St., Columbia 8, South Carolina, or with the SPE National Office.

spe

Edited by Philip G. Fleming
Bendix Aviation Corp.

COMMITTEE REPORTS

National Credentials Committee

George Baron, Chairman, reports that during the period September 1, 1958, through January 15, 1959, the National Office had sent to the National Credentials Committee for processing, a total of 486 applications for membership in SPE and 12 requests from members of SPE for reclassification.

These 498 forms went out in 17 mailings. From the date the mailing was prepared in the National Office, through its circulation among the committee members the entire process was accomplished in from 8 to 20 days. However, the majority completed their rounds in the average of 12 days.

Meetings Committee

Frank Martin, Chairman, reports that the Meetings Committee personnel for the past year has included D. R. Bowlin, S. H. Greenwood, D. A. Hamilton, G. A. Martinelli, J. E. Parks, J. A. Picard, C. H. Whitlock, and F. A. Martin. During the past month Franklin Fine, who has been nominated as general chairman of the 16th ANTEC, was appointed to the committee.

Mr. Martin's summary of the work accomplished by this committee during 1958 shows that the goals—set for the year, were substantially completed. He included the following goals for 1959.

Looking to 1959 there are several items which the Meetings Committee should study. Among these are (1) revision of the system for allocating RETECS, (2) Study of the type of papers presented at ANTECS, and regarding their quality, and (3) Study of functions that can be shifted from the local ANTEC committees to the National Office Staff.

Professional Activities Groups

Dr. Frank Reinhart, Administrator, Professional Activities Groups (1958), indicated that significant progress was made in PAG during 1958. With approval of Plastics in the Automotive Industry there are now 15 PAG's. Eight of these groups are very active, three are less active, and two groups held initial meetings at the 1959 ANTEC.

In order to expedite the proper flow of communications, the following number and initial designations have been allotted to the standing PAG's.

PAG 1.	Plastics in Buildings	PIBPAG
PAG 2.	Plastics in Electrical Insulation	PEIPAG
PAG 3.	Extrusion	EXTPAG
PAG 4.	Reinforced Plastics	REPPAG
PAG 5.	Injection Molding	IJMPAG
PAG 6.	Metals for Plastics Molds	MPMPAG
PAG 7.	Casting and Plastics Tooling	CPTPAG
PAG 8.	Forming	FMGPAG
PAG 9.	Finishing	FHGPAG
PAG 10.	Thermosetting Molding	TSMPAG
PAG 11.	Vinyl Plastics	VYPPAG
PAG 12.	Polymer Structure and Properties	PSPPAG
PAG 13.	Fabricating	FABPAG
PAG 14.	Standards for Reporting Properties	SRPPAG

PAST PRESIDENTS ADVISORY BOARD LUNCHEON

The traditional annual luncheon of SPE Past Presidents, which comprised the membership of the Past Presidents Advisory Board, was held on January 29th at the Hotel Commodore in New York City. Nine of our seventeen Past Presidents attended the luncheon and posed for the above picture. Seated from left to right are: John W. LaBelle (1954); Fred C. Sutro, Jr., 1959 National President; R. Kenneth Gossett (1958); Thomas A. Bissell, Executive Secretary, Islyn Thomas (1951) and Frank W. Reinhart (1955). Standing left to right are: J. Harry Dubois (1948); William O. Bracken (1952); Jerome Formo (1956); Mario J. Petretti (1949) and Walter F. Oelman (1953). During the luncheon, the group discussed several projects which the SPE Past Presidents Advisory Board will study this year under the Chairmanship of Peter W. Simmons (1957).

PAG 15. Plastics in Automotive Industry PAIPAG

In a summary rendered by Dr. Reinhart on membership and activities of various PAG's, it was noted that PIBPAG had held 3 meetings since January 1958 and projects presented on those occasions are now being worked on. PEIPAG had participated as co-sponsors in the 1958 National Conference on the Application of Electrical Insulation in Cleveland, Ohio, September 1958. This group, in cooperation with the Northern Indiana Section, has planned a RETEC on Plastics in Electrical Insulation for May 22, 1959 (see page 250). National Council has approved this conference. In the February issue of the Journal (page 166) is a report on the plans of EXTPAG concerning their "Extrusion Workshop."

Regular active sessions of the New York and Detroit REPPAG has formed a subgroup to develop a standard format for presenting properties of reinforced plastics for the design engineer. Recommended by REPPAG for the National Council to consider is the problem of a comprehensive abstracting service for articles on plastics and related services. Formation of an Ad Hoc Committee to study the establishment of an SPE Abstracting Service has been requested of National Council.

FHGPAG helped to organize one of the sessions at the 1959 ANTEC. They are also organizing a RETEC in cooperation with the Buffalo Section to be held October 16, 1959. Attempts are being pursued by TSMPAG to set specific tasks and to delineate the scope of activity. PAIPAG, a new group has been formed and approved by Council. It has 18 members.

Over 60 representatives of various segments of the vinyl industry attended the National Vinyl Professional Activity Group when it met in January during the 15th ANTEC at the Hotel Commodore in New York City. Three goals of the VYPPAG are to (1) Aid in forming local VYPPAC Sections. Two subgroups have been formed to date. One is in New York and the other in New England. A third subgroup is being formed in Northern Ohio; (2) Provide liaison on programs between VYPPAC Sections; and (3) Provide suitable technical papers for presentation at ANTEC. They have requested responsibility to plan vinyl programs at National Conferences. Interested persons should contact the secretary, Joseph Clancy at 4343 East River Drive, Philadelphia 29, Pa.

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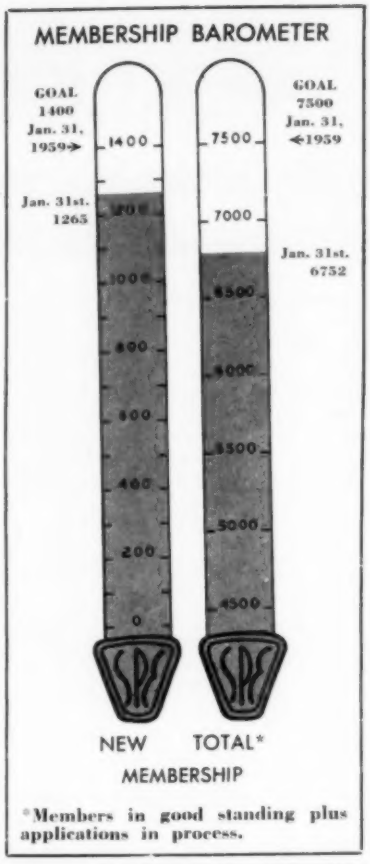

*Members in good standing plus applications in process.

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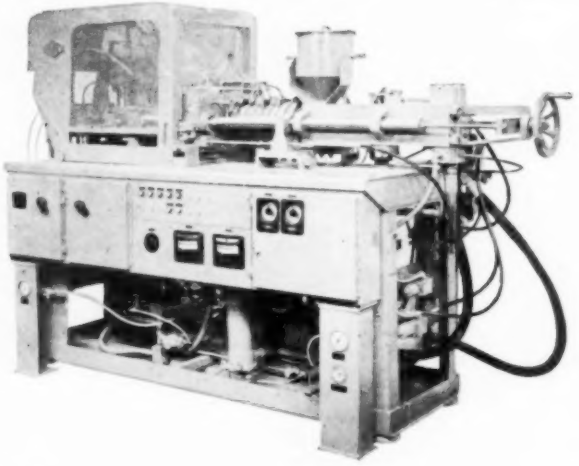
- separate injection and clamp hydraulic circuits
- shock mounted control panel
- photo electric recycling monitor
- 75 ton clamp
- 9¼" stroke
- fully automatic

*dependent on material and mold construction



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Plastics in the Metals Industries

Sponsored by the Pittsburgh Section
Penn-Sheraton Hotel, Pittsburgh, Pa.
May 7, 1959

8:30 A. M.—REGISTRATION

MORNING SESSIONS

Session I

MODERATOR: Dr. M. W. Lightner
Vice-President—Applied Research
U. S. Steel Corporation

10:00-10:30 A. M.

TEFLON AND METALS—
R. B. Fehr, Jr.
E. I. du Pont de Nemours Co.

10:30-11:00 A. M.

PENTON, A CONSTRUCTION METAL, FOR CORROSIVE APPLICATIONS
Clarence S. Miller
Hercules Powder Company

11:00-11:30 A. M.

LEXAN, A NEW ENGINEERING MATERIAL
R. J. Thompson
General Electric Company

11:30-12:00 M.

HIGH DENSITY POLYETHYLENE
O. E. Larsen
Phillips Chemical Company

Session II

MODERATOR: Dr. P. W. Bachman
Vice-President & Director of Research
Koppers Company

10:00-10:30 A. M.

PLASTICS LINED TANKS
W. P. Cathcart
Tank Lining Corporation

10:30-11:00 A. M.

MAINTENANCE USES OF NYLON IN THE METAL INDUSTRY
Robert Koch
Polymer Corporation

11:00-11:30 A. M.

ALUMINUM IN FOAMED PANELS
L. W. Hovland, *Aluminum Co. of America*, and Prof. E. R. McLaughlin, *Pennsylvania State University*

12:30 P. M.—CONFERENCE LUNCHEON

J. H. DuBois, *Consultant*
"LOOKING AHEAD IN PLASTICS"

AFTERNOON SESSIONS

Session III

MODERATOR: B. M. Hollansworth
Superintendent of Engineering
McKinney Manufacturing Company

2:30-3:00 P. M.

NYLON AND DELRIN RESIN APPLICATION IN THE METALS FIELD
R. N. Peterson
E. I. du Pont de Nemours Co.

3:00-3:30 P. M.

POLYPROPYLENE IN FABRICATED EQUIPMENT
Dr. W. Paul Acton
Hercules Powder Company

3:30-4:00 P. M.

PLASTICS AS CONSTRUCTION MATERIAL IN THE STEEL INDUSTRY
Dr. Joseph Bigos
United States Steel Corporation

Session IV

MODERATOR: E. E. Lull
Assistant Manager Tool Steel Sales
Crucible Steel Co. of America

2:30-3:00 P. M.

EXTENDING THE HORIZON FOR STEEL SHIPPING CONTAINERS WITH THE USE OF PLASTICS
E. B. Edwards
Jones & Laughlin Steel Corporation

3:00-3:30 P. M.

HIGH DENSITY PROTECTIVE COATING
S. M. Hmiel
Koppers Co., Inc.

Pre-registration forms are available from Chairman John Parks, Hydraulic Press Mfg. Co., 512 Empire Bldg., Pittsburgh 22, Pa.

spe

TECHNICAL MEETINGS CALENDAR

16TH ANTEC

ANNUAL TECHNICAL CONFERENCE—January 12-15, 1960, The Conrad Hilton, Chicago, Ill. Sponsored by the Chicago Section. For more information, contact General Chairman Franklin L. Fine, Rohm & Haas Co., 5750 W. Jarvis Ave., Chicago 31, Ill.

1959 NATEC

NATIONAL TECHNICAL CONFERENCE—October 13-14, 1959. The Ambassador, Los Angeles, Calif. For more information, contact General Chairman, Jack G. Fuller, % Chemtrol Co. 10872 Stanford Ave., Lynwood, Calif.

WORKSHOP

EXTRUSION—April 1 and 2—Lowell Technological Institute, Lowell, Mass. Sponsored by the Eastern New England Section in cooperation with the Extrusion PAG. For more information, including complete program, see pages 166, 167 of the February SPE Journal. For further information contact Robert D. Sackett, 15 Western View Circle, East Longmeadow, Mass.

RETECS

A DESIGNER'S LOOK AT REINFORCED PLASTICS FROM THE PLEASURE BOAT, AIRCRAFT AND MISSILES INDUSTRIES VIEWPOINT—April 28, 1959, Adolphus Hotel, Dallas, Texas. Sponsored by the North Texas Section. For information write to Chairman William McConnell, Air Accessories, Inc., 1400 Henderson St., Ft. Worth, Texas. For complete program see page 235 of this issue.

PLASTICS IN THE METAL INDUSTRY—May 7, 1959, Penn-Sheraton Hotel, Pittsburgh, Pa. Sponsored by the Pittsburgh Section. For information write to Chairman John Parks, Hydraulic Press Mfg. Co., 512 Empire Bldg., Pittsburgh 22, Pa. For complete program see page 249 of this issue.

PLASTICS IN ELECTRICAL INSULATION—May 22, 1959, Fort Wayne, Ind. Sponsored by the Northern Indiana Section in cooperation with the Plastics in Electrical Insulation PAG. Program includes papers on encapsulation, printed circuitry and fluidized bed coatings. For information write to Chairman Walter A. Gammel, Sr., RBM Controls Div., Essex Wire Corp., Logansport, Ind.

PLASTICS IN THE AUTOMOTIVE INDUSTRY—June 19, 1959. Sponsored by the Detroit Section in cooperation with the Plastics in the Automotive Industry PAG. For information write to Chairman John Donalds, The Dow Chemical Co., 450 Fisher Bldg., Detroit 2, Mich.

VINYL PLASTICS—October 7, 1959, Cleveland, Ohio. Sponsored by the Cleveland Section. For information write to William Messina, 414 Shawnee Place, Huron, Ohio.

PLASTICS FINISHING—October 16, 1959, The Niagara Hotel, Niagara Falls, N. Y. Sponsored by the Buffalo Section in cooperation with the Plastics Finishing PAG. For information write to Chairman Gordon K. Storin, 3 Forest Rd., Lewiston Heights, Lewiston, N. Y.

PLASTICS IN THE SHOE INDUSTRY—November 1959, St. Louis, Mo. Sponsored by the St. Louis Section. For more information write to Otto Wulfert, Chairman, % Wagner Electric Co., 6400 Plymouth Ave., St. Louis 14, Mo.

PLASTICS IN PACKAGING—November 19, 1959, San Francisco, Calif. Sponsored by the Golden Gate Section. For information write to Chairman Bill Hodges, Hodges Chemical Corp., 1801 Spring St., P.O. 190, Redwood City, Calif.

STABILITY OF PLASTICS—December 1959, Washington, D. C. Sponsored by the Baltimore-Washington Section. For information write to George Flanagan, 1112 19th St., N.W., Washington 6, D. C.

PAG MEETING

STANDARDS FOR REPORTING PROPERTIES—April 15, 1959, National Bureau of Standards, Washington, D.C. Election of officers and establishment of a scope of activity will take place. Advise Executive Secretary, Tom Bissell or PAG Administrator, Frank W. Reynolds, by April 1, 1959, of your plan to attend. For convenience, this meeting is held in conjunction with the Baltimore-Washington forum to be presented the preceding day as stated below.

TECHNICAL FORUM

BALTIMORE-WASHINGTON—April 14, 1959, National Bureau of Standards, Washington, D.C. Presentation of eight papers are to be made. A tour of the facilities of the Bureau will follow. For information write to Dr. Irving Wolock, 2209 Richland Pl., Silver Spring, Md., or phone him at Naval Research Lab. Note above schedule for meeting to follow on April 15th.

SECTION MEETINGS

CENTRAL INDIANA—March 31, 1959, Warren Hotel, Indianapolis, Indiana. A panel discussion will be held on "Preventive Maintenance of Plastic Equipment."

WESTERN NEW ENGLAND—April 1, 1959, Bradley Field, Windsor Locks, Conn. Guest speaker Dr. E. C. Bernhardt, will discuss "The Use of an Extruder for Non-Continuous Operations."

CHICAGO—April 13, 1959, Western Society of Engineers Building. W. F. Christopher will give a talk on "Lexan Polycarbonate Resin."

NEW YORK—April 15, 1959, Governor Clinton Hotel, New York City. Irwin L. Podell will moderate a discussion on "Epoxy Plasticizers for Vinyls." Joseph Fath will speak on monomeric epoxies, and R. F. Conyne's subject will be on polymeric epoxies.

PITTSBURGH—April 17, 1959, Sherwyn Hotel, Pittsburgh, Pa. "Roll of Plastics in Industrial Design," will be discussed by Peter Muller-Munk.

SECTION NEWS

Akron

Section Organization

Merle J. Sanger

Organization of the Akron Section of SPE has been completed and was chartered by the National Council on January 26, 1959. Members of this new Section were formerly affiliated with the very active Akron-Cleveland Section of SPE. Separation from this group was done only for the convenience of the plastics engineers in the local areas to attend technical meetings.

Membership of this Section now numbers 102 with an anticipated growth.

Officers of the Akron Section are: President—Don Siddall; Vice President—Richard H. Juve; Secretary—W. H. Nicol; Treasurer—Milan Krajcik.

The February meeting featured a local speaker who entertained with an informal discussion. Purpose of this meeting was to allow an opportunity for members to become better acquainted.

Chicago

New Directors, Officers

Harry E. Bennett

The Chicago Section of the SPE has recently elected three new directors of the board, Joe A. Gits, Charles Waugh and Harry E. Bennett. These new officers have taken their position on the board along with the present board of directors: Ray Daniels, Earl Wilson, William Brown, James Goulka, Robert Reynolds, Frank Moore, Gib Baccash and Frank Fine.

The Board of Directors is concentrating on monthly programs for the year as well as the 1960 16th Annual Technical Conference which is headed by Frank Fine. Mr. Fine has had experience with the promotion of similar meetings and we have excellent hopes that the 1960 event will be the best engineering technical conference produced.

Setcion Officers are: President—Ray Daniels; Vice President—Earl Wilson; Secretary - Treasurer—William Brown.

Quebec

New Officers

E. W. May

The Quebec Section met January 12th, and elected the following slate of officers for the year 1959: President—L. J. Powers, Ontario Steel Products Co. Ltd.; Vice President—W. B. Jonah, Lewis Specialties Ltd.; Honorary Secretary—L. A. Meredith, Canadian Industries Ltd.; Honorary Treasurer—W. Lukian, Lukian Plastics & Engineering Co.; National Councilman—M. F. Malone, Canadian Resins & Chemicals Ltd.

A joint SPE-Quebec Rubber & Plastics Group Meeting was held in Montreal at Ruby Foo's, January 15th. The guest speaker was J. C. MacDonald, P. Eng., of the Chrysler Corporation of Canada Limited, who delivered a most interesting talk on the present and future requirements for plastics by the automotive industry.

Newark

Guest Speakers

David L. Sahud

During the February meeting at Military Park Hotel, Section President Allen Serle announced that membership now totaled 661 and disclosed the formation of the new Polymer Structure and Properties PAG which was consummated at the recent New York ANTEC. Ben Walker, Chairman of the Library Committee, described the Section's extensive plastics library, which was instituted in conjunction with the educational program at the Newark College of Engineering. This modern library is available to all SPE members.

A program of two talks was presented by Chairman Seymour Bodner. Mr. Watson C. Marriner, of DuPont, spoke on "Designing with Delrin Acetal Resin." Slides were shown.

Mr. R. Eugene Lowey, of Hale and Kullgren, discussed "New Extruder Developments," emphasizing those introduced by using induction heating. Pictures were also used.

New York

Technical Discussion

Charles C. Orr

Nearly 200 members and guests gathered February 18th at the Governor Clinton Hotel to attend New York Section's first 1959 meeting. Section President Herbert Weber announced that since ANTEC, New York has acquired 75 new members bringing total membership to 775. Following other business announcements, he awarded the Section's traditional gavel to Section Past President George Leaf, for his work during 1958.

Soren Graae, Blow-O-Matic Corporation, addressed the general meeting on "Blow Molding of Plastics With Blow-O-Matic Equipment."

"Printing and Decorating of Polyethylene Objects," was discussed by Michael A. Spina, Interchemical Corporation. After extrusion, the surface of a polyethylene object must be modified so that it will receive printing inks. The ideal situation would be to treat only the first molecular layer, but since this is not practical, the goal is to penetrate the surface as little as possible. Four principle methods of treatment were discussed. These include: chlorination, differential heat treatment, oxidation, and electronic treatment.

The VIPAC meeting drew about 90 members. J. L. Hutson, General Tire & Rubber Co., talked "Characterization of Vinyl Resins by Viscosity." The most meaningful method of expressing molecular weight of vinyl resins is in terms of its intrinsic viscosity. Mr. Hutson defined the relationship of the various molecular weight resins to ultimate resin properties.

Robert Braddicks, Jr., Kentile Inc., discussed "Improved Classification of Vinyls."

The Thermoformers sub-group was addressed by W. P. Gideon, Eastman Chemical Products, Inc.

Southern Section

Plant Tour

Sam Rutland

The Southern Section included a very interesting plant tour in its fall meeting schedule. Approximately 55 members and guests were taken on a tour of the Marietta, Georgia Division of Lockheed Aircraft Corporation. The primary interest of the group was the Production Plastics Shop where plastics parts for the C-130 Hercules propjet transport and the B-47 Stratojet six-engine jet bomber under modification for the Air Force are fabricated. Parts fabricated include glass mat and fabric reinforced polyesters and epoxies, formed acrylic, Orlon reinforced acrylic, Teflon, phenolic, and polyethylene parts. A large majority of the fabricated parts are structural and non-structural aircraft parts made from glass reinforced polyester resins by the matched metal molding technique and by vacuum bag layup. Such parts include radomes, fairings, electrical junction boxes, equipment storage boxes, aircraft skis, hot and cold air ducts, antenna windows, air scoops, etc. Structural load-carrying parts are made from glass fabric reinforcing usually by the hand layup vacuum bag method, whereas non-structural or non-critical parts are ordinarily made from glass mat reinforcing by press molding with mated Kirksite or aluminum dies. High quality void-free structural laminates made by the vacuum bag technique usually run in exces of 45,000 psi tensile strength and 60,000 psi flexural strength. An integrally molded test sample is taken from each structural part and tested for flexural strength for quality control.

In addition to viewing the Plastics Shop, the group was taken on a tour of the C-130 production line, the B-47 modification line and the Jet-Star jet utility cargo mock-up.

Connecticut

Injection Machines

K. C. Clarke

"Improved Injection Machines" was the subject for the meeting held on February 13th at the American Brass Company's Club in Naugatuck. Neil J. Henry, Sales Engineer for Reed-Prentice, described the efforts of his company in providing the plastics industry with better conventional injection machines and entirely new machines based on new concepts.

New conventional machines must have greater speed, daylight, pumping capacity, versatility, and ease of maintenance.

The entirely new machine described by Mr. Henry is called the Jetflo. This machine employs a rotating hollow screw for plastifying the resin, and a reciprocating ram operating within the screw for injection. The advantages offered by this machine are: (1) more uniform plastifying of the resin, (2) stronger and tougher pieces, (3) reduction in operating temperatures and pressures, (4) improved color dispersion.

Many case histories were cited to substantiate these advantages. Mr. Henry was kept busy the remainder of the evening answering questions on this new concept in injection molding machines.

Kentuckiana

Epoxy Resin Talk

R. O. Carhart

Newly elected officers presided at the January 21st meeting which was held at Bill Boland's Dining Room, where 21 members and guests attended. New officers are: President —Ray Eshenaur; Vice President— Darryl Hicks; Secretary — Randy Carhart; Treasurer — Bill Watkins and National Councilman — Jack Berutich.

Following the dinner, President Eshenaur introduced the speaker for the evening. Dr. Harold Cook, who is a member of our Section, gave an interesting and informative talk on epoxy resins, covering chemistry, formulation, properties and applications of such materials. An interesting display of use applications was also provided.

Ontario

Officers Named

Harry Watson

John Glen, district sales manager of plastics, C-I-L, Toronto, was elected President of the Ontario Section. Other officers were; Vice-President—Norman Hall; Treasurer —Harold Hutton; Secretary—Harry Watson.

R. A. Noble, Canadian Industries Ltd., Toronto was elected National Director.

Ten samples tested 2 minutes apart in the

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FAST No double weighing, desiccator cooling or calculating. Moisture contents determined in 2 minutes on production line basis.

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Southeastern Ohio

Plastic Tooling and Mold Making

William J. Stranathan

President S. M. Bazler, General Electric Company opened the November meeting, held at the Pioneer Room of the Berwick Hotel, with a discussion on future meetings. The meeting was turned over to Edward Michl, General Electric Co., Program Chairman, who introduced Paul Smith, Cambridge Tool & Die Co. He commented briefly on the program for the evening which was in the form of a plant tour and demonstrations by employees of Cambridge Tool & Die Co. Different phases of mold making was discussed and a question session followed.

"What the Past Twelve Years Have Taught Us Not to Do In Plastics Today" was the topic of Mr. Smith's talk. Use of cheap molds as a means of economizing was an interesting point, and he stressed the hiring of good toolmakers.

Following, William Stranathan led a discussion on Mold Estimating and Design, and included a brief talk about Shielded Gas Arc Welding and its use in the tool industry. He stated that the basic cost of a mold is dependent on the number of cavities required and the intricacy of their shape.

Central New York

Molding Techniques

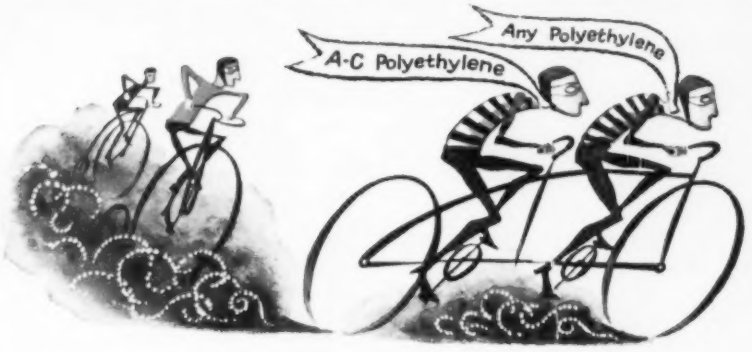
Frederick E. Ruhe

A varied program of the January meeting was attended by 33 members and guests. An excellent report on the Educational Committee meeting and future plans for SPE was presented by President and National Councilman Jim Lampman.

Larry Ulmschneider of Eastman Kodak Company, Rochester, New York, was guest speaker. Mr. Ulmschneider has been employed by Eastman Kodak for 30 years and was an early development engineer and designer of injection molding machinery.

Other guests on hand were Paul Ulmschneider and two fellow engineers of General Electric in Utica, and Jack Bent of Eastman Chemical Products in Rochester.

Blend Polyethylene with Polyethylene...



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St. Louis

Film on Color

Lyle R. Dean

The January meeting was held at Roncaro's. Results of the recent election were announced with the following elected to the Board of Directors: J. G. Lake, L. E. Lada, and B. M. Coons. The new officers are as follows:

President—Thomas O. McNearney, Jr.
Vice President & Program Chairman—Jack G. Lake
Secretary Recorder—Lyle R. Dean
Treasurer—R. S. Baumgartner
Membership Chairman—Wayne DeCamp
National Committeeman—Donald E. Eells

The speaker of the evening was Mr. Richard L. Lynch, Sales Manager, RBH Division, Interchemical Corporation. Mr. Lynch showed a film produced by Interchemical Corporation, "This is Color." The film was on the physics of color. After the film, Mr. Lynch emphasized some of the points brought out in the film with slides and answered many questions brought up by the members. During his talk, Mr. Lynch explained that the study of color was one of the oldest of arts but one of the newest of sciences. He went on to say that color is broken-down into three main areas: (1) Physics of Color, (2) Cycle Physics of Color, and (3) Psychology of Color.

Toledo

Tour Ford Plant

R. E. Dunham

For the February meeting, the Toledo Section of SPE made a plant tour Feb. 18 of the Compression Molding Operation of the Hardware and Accessories Division, Ypsilanti Plant of the Ford Motor Company. An excellent turnout of over 60 members and guests observed molding of distributor caps, coil tops, pump impellers, insulators, and heater housings. Messrs. Jim Tennant, Robert Beaver, and Ken Merritt of Ford Motor Company were hosts.

Materialwise, Ford has considerable diversification in this plant with phenolics, alkyds, and polyester premix being molded. The volume of premix polyester made and converted into heater housings is enormous and the new equipment and molds engineered for this application represent culmination of a major engineering development. Alkyds are handled as powder and in rope form.

The successful use of high frequency powder preheating on a large scale to produce short cycles on molding thick section pieces, indicates the modernization present in the Ford operation. Fast-acting large presses using a minimum of labor were also good evidence of the refinements in operation.

Finishing equipment specially designed to handle the parts produced were observed completing the job of producing the desirable items. To see a molded item assembled into the final complete automobile heater was also very satisfying.

Miami Valley

Printed Circuits

Stephen D. Marcey

The Miami Valley Section started off the year by having a dinner meeting at the Wishing Well in Centerville, Ohio. Speakers for the evening included St. John Bain, technical service engineer for the Formica Co., and R. Kenneth Gossett, 1958 National President of SPE.

St. John Bain presented the following topic: "The Effect of Processing and Environment on Printed Wiring Laminates". Samples were used to illustrate some of the Formica products related to the printed circuit industry. A discussion and answer period followed.

R. K. Gossett stressed briefly the following points: 1) the *SPE Journal* had increased in size due to more advertising; 2) the 1959 ANTEC in New York City promises to be bigger and better than ever; 3) attendance at the RETECS has been increasing; 4) recent advancements in student member program with various educational institutions; 5) creation of four new SPE sections in the midwest area; 6) activities of the PAG groups.

F. W. Reynolds, 1958 National Membership Committee Chairman, a guest at the dinner meeting was asked to comment on membership activities. He suggested several ways of increasing the local membership in the SPE.

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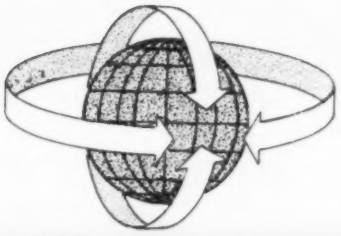

PLASTICS AROUND THE WORLD

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ARGENTINA

PLASTICOS
August-September 1958
Abstracter: John B. Ballard

1958 Technical Course—Editorial

The 1958 technical course of the Argentine Chamber of the Plastics Industry started in June with a capacity crowd of 183 persons enrolled. The course will continue with weekly meetings, ending in October. The subject matter covers all types of plastics materials, manufacturing methods, and equipment.

October-November 1958
Abstracter: John B. Ballard

New Raw Material Crisis—Editorial

Government limitations on importing raw materials are again seriously threatening the development of the plastics industry. Importation of all material was suspended for several months, and at present only certain types of material can be imported and this with special permission.

★

GERMANY

KUNSTSTOFFE
July, 1958
Abstracter: Charles S. Imig

Plastics After the First Six Months of 1958—Dr. Ing—Karl Mienes

This is an outline of recent technical development applications in the plastics field. Among the resins covered are polyethylene, polypropylene, polyvinyl chloride, polystyrene, polyamides and polyurethanes.

Polyethylene—Dr. Ing—A. Schwarz

This article offers a rather concise resumé of the nature of ethylene polymers. Relationship of crystallinity to properties such as density and stiffness are covered in addition to a discussion of what polymer properties affect such important properties as environmental stress cracking, tensile strength, compressive strength. Stabilization of the polymers against degradation is also reviewed.

Characterization of Electrical Surface Leakage Using a Drop-Method and Limiting Stress—Dr. Ing—Walter Claussnitzer and Viktor Siegel

Surface leakage of insulating materials is tested by dropping an electrolute between two electrodes at 380 volts AC. This paper discusses the relative merits of reporting the minimum limiting voltage below which no surface leakage occurs versus reporting the limiting drop number at a fixed voltage.

Plastics and Plastics Machinery at the German Industries Fair—Dr. J. Hausen

Further developments in plastics machinery including high-speed automatic molding machines and extruders with revolving mold stations were of special interest at the Fair as was the presence of exhibits by "non-plastics" industries.

Plastics at Brussels—Dipl.-Ing. Amtor Schwabe

This is a brief review of the numerous examples of the use of plastics in construction seen at the Brussels World Fair.

Twelfth Conference of the GDCh-Group "Plastics and Rubber" in Bad Nauheim—

This article reports the many papers presented at this conference. Papers ranged in subject matter from polyethylene to kinetic studies of vulcanization.

Recent Developments in the Fabrication and Processing of Rigid Polyethylene Semi-Finished Materials—Dr. E. Rottner

Latest developments in this field are covered by the author. Many practical examples are given including new equipment as well as new applications. Among the examples are sinks and duct work.

Use of Polyethylene Coated Filter Pipes in Well Construction—T. Engel

Corrosion protection of pipes used in well construction is particularly difficult because of the high pressures resulting from the great depths. A method of coating steel pipes with polyethylene is described which provides excellent protection against chemical and electrolytic corrosion.

August, 1958
Abstracter: C. S. Imig

Plastics Plans Behind the Iron Curtain—

The plastics industry is admitted to be much behind but Mr. Khrushchev outlined a 7-year expansion program to catch up. Plans are to purchase complete installations to speed the program.

★

ITALY

POLIPLASTI
September-October 1958
Abstracter: Alfred L. Alk

Using Silon in Railroad Rolling Stock—Ivar Hilken and Zdenek Tresnak

In 1953 a research program was started with the idea of eliminating the need for scarce, weight-reduced materials. Plastics were found to be better than conventional materials in many instances. Silon, which is a polyamide produced in Czechoslovakia was used in an electric locomotive axle bearing and friction support plates, where in such areas of combined heavy loads and small movements, difficult lubrication was often experienced, and replacements were costly. Ordinarily 300-400 pounds of bronze was used in these parts. Since its initial installation 3 years ago, excellent service has been obtained and it is expected to outlast bronze by at least twice as many years of service.

In the bearing replacements, the Silon used was either in the form of internal bushing or sleeves applied on the ends of shafts and journals. In the case of the former use, the shaft was first treated with heat and turned to a mirror finish to prevent wear on the bearing insert. However, if the shaft was coated, it was unnecessary to turn down any elliptical wear since the difference was taken up by the plastic. Silon is also used in the main supporting assembly of the locomotive undercarriage in the form of sleeves slipped over the lateral shafts as well as in the form of an anti-friction gasket. Silon simplifies assembly, doubles the life of the joint, eliminates frictional heat and provides a smoother ride.

★

CANADA

CANADIAN PLASTICS

December 1958

Abstracter: Samuel S. Oleesky

This entire issue is devoted to a summary of the plastics business in Western Canada. The entire industry is covered in a comprehensive, terse manner and includes films, adhesives, acrylics, plastics pipe, reinforced plastics and various segments of the molding field.

Perhaps the two most interesting items cover the molding of nylon propellers for marine use and the rehabilitation program at Oakalla prison farm, near Vancouver. American industry might well be inclined to examine the latter program, since it involves the training of an average of twelve inmates in the highly specialized field of reinforced plastics. These men are taught to build boats, skis, furniture, etc., and when released from custody are competent to augment the ranks of badly needed skilled labor.

For men associated with the plastics industry in the U.S., a study of this issue will be a revelation. Most of us have forgotten the growing pains that are only now racking the bones of our Canadian brothers, and the ingenious way in which they have met their challenges is an inspiration from which we all may take heart and, probably learn something.

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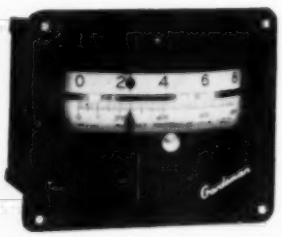

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FRANCE

L'OFFICIEL DES MATIÉRES PLASTIQUES

October 1958

Abstracter: Alexander Baczewski

Stabilization of Poly(Vinylchlorides)—Fernand Chevassus

This article is an abstract written by one of the authors of a book bearing the same title and written with the collaboration of R. de Broutelles.

Stability of vinyl resins against breakdown on heating is needed in order to prevent a deterioration of the dielectric properties. Acid acceptors are needed and lead salts, e.g. the silicates or the carbonates, are recommended. The carbonate, though, leads frequently to gassing and causes surface irregularities. Differences in index of refraction caused by varying the plasticizer makes it sometimes advisable to use lead phthalate or lead salicilate. The synergism with tin, cadmium, barium and strontium stabilizers is described and the importance of actual life tests in comparison with weather-o-meter tests is stressed. Pigments should be free of breakdown catalysts, e.g. iron or zinc. A table showing the influence of various classes of plasticizers upon the stability of a vinyl resin containing dibutyl tin dilaurate concludes the article.

Poly(Vinylchlorides) Manufactured In France—Anon.

A table gives the trade names, manufacturers, method of polymerization and principal uses of 47 resins.

The Coloring of Thermoplastic Materials—M. F. Coffinières

The author, who is the president of the "coloring" section of the French counterpart of our SPI, describes the extrusion blending of colors and plastics.

Manufacture of Vinyl Compounds By The So-Called Dry Blending Process—Fernand Chevassus

This article compares various American methods of dry blending vinyl resins. Advantages and limitations of this method are shown.

★ ★ ★

ABOUT MEMBERS

Dr. Herman S. Kaufman has been appointed to the staff of Allied Chemical's Central Research Laboratory, Morristown, N.J., it was announced by C.P. Hackett, director of research and development. Dr. Kaufman will serve as technical assistant to Dr. George G. Joris, manager of research at CRL. A native of New York, Dr. Kaufman received a B.A. degree in chemistry from Brooklyn College in 1942 and a Ph.D. degree in physical chemistry from Polytechnic Institute of Brooklyn in 1947. Dr. Kaufman is a member of the ACS and SPE, Newark Section.

William F. Condon was appointed technical sales representative by U.S. Polymeric Chemicals, Inc., Stamford, Conn., prepreg producer, according to a recent announcement by Howard T. Cusic, sales manager for the firm. Mr. Condon will cover the aircraft and missiles field as well as the electrical industry. Prior to joining U.S. Polymeric, he was sales vice president for Cordo Molding Products, Inc. He is affiliated with the New York Section of SPE.

Robert B. Jacob, president of Cadillac Plastic and Chemical Co., has been nominated to the board of directors of the Dayton Rubber Co., president Clowes M. Christie announced. Mr. Jacob founded Cadillac Plastic and Chemical Co. in 1946. He is affiliated with the Detroit Section of SPE.

Robert B. Jacob

Joseph Meyer

Joseph Meyer has been appointed sales representative for Auburn Plastics, Inc. of Auburn, N.Y., according to an announcement by E. M. Woodruff, vice president. Mr. Meyer will be responsible for the New Jersey and metropolitan New York territory. Meyer has 25 years experience in the plastics field. He formerly represented the Prolon Plastics division of the Prophylactic Brush Co. in custom molding and was manager of the Newark, N.J. office of the Chemical Div. of the General Electric Co. prior to joining Prolon. He is a member of the SPE, Newark Section.

Kenneth Fietz was named manager of the San Francisco sales office for U.S. Industrial Chemicals Co., it was announced by Alden R. Ludlow, sales vice president of this company. Mr. Fietz has been a representative of the firm's New York sales division for the past 16 years. He is affiliated with the Newark Section.

Justin Zenner, who was an affiliate of the Chicago Section of SPE, died recently. Mr. Zenner was a representative of Injection Molders Supply Co., in the Chicago area.

Lewis Connelly is the new sales representative in the Dallas-Fort Worth area now for Eastman Chemical. His office was moved from Houston recently. Eastman has just put into operation its new polyethylene plant at Longview. Mr. Connelly is affiliated with the South Texas Section of SPE.

Charles L. Andrews, III, SPE Chicago Section, has joined the Chicago Molded Products Co., as manager of their material and process laboratory. Prior to this he was technical representative with Dixon Corp. in Bristol, R. I.

Glenn F. Blinzler has been promoted to western district manager in charge of Marlex sales at Pasadena, Calif., for Phillips Chemical Co., Plastics Sales Div. Mr. Blinzler, an affiliate of the Chicago Section, succeeds **Richard G. Askew**, Southern California Section, who has been promoted to export manager of Phillips with headquarters in New York City.

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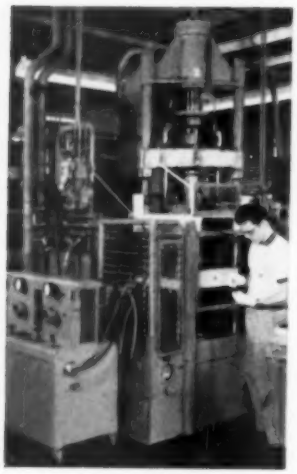

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Vol. V, 1959, New York City, 96 papers. $7.50, members; $12.50, non-members. Single preprints of individual papers, Vol. V, while they last, $0.25 each, members; $0.40 each, non-members.

Vol. IV, 1958, Detroit, 94 papers. $5.00, members; $7.50, non-members.

Vol. III, 1957, St. Louis, 60 papers. $5.00, members; $7.50, non-members.

RETEC PREPRINT BOOKS

★ AUTOMOTIVE

Plastics for the Automotive Industry—Detroit Section, 6 papers. $2.00, members; $3.50 non-members.

★ BUILDING

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Plastics in Electronics—Golden Gate Section, 8 papers. $2.50, members; $3.75, non-members.

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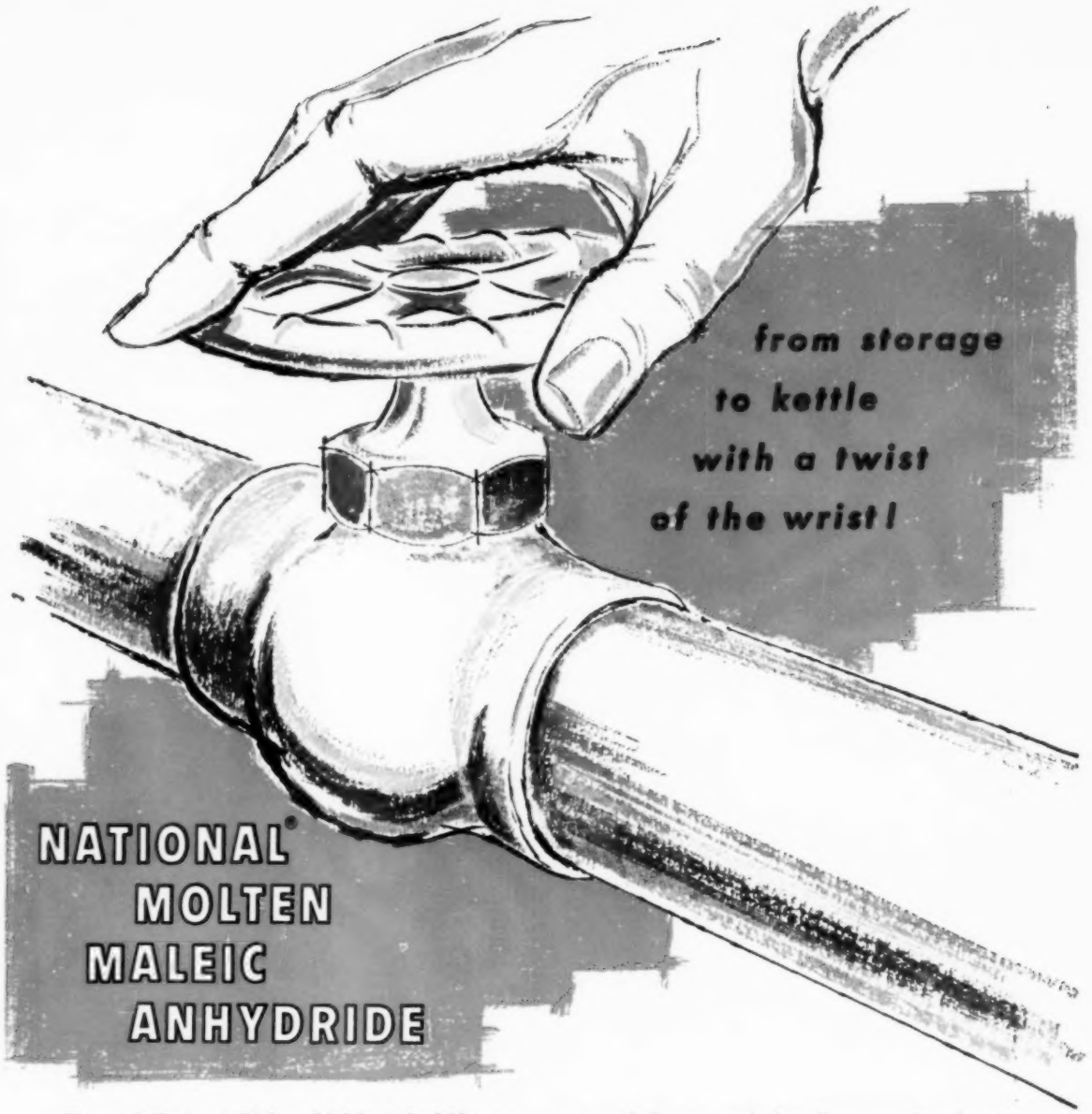

Users of National *Molten* Maleic Anhydride save 1¢ per pound, have lower in-plant handling costs and can get greater through-put from present equipment.

You, too, may be able to benefit substantially.

Since we make every form of Maleic Anhydride, we can give you unbiased figures on the net cost of solid vs liquid at your volume of use and plant location.

Whichever form of National Maleic Anhydride you choose, you'll be getting a uniform, high-purity product made by our exclusive, direct, continuous catalytic-oxidation process. And you'll get excellent service by rail or truck from our well-located plants at Moundsville, West Virginia and Buffalo, New York.

WRITE FOR TECHNICAL BULLETIN C-2

Why not discuss possible use of National Molten Maleic Anhydride with us? Meanwhile, ask for our 12-page Technical Booklet C-2 which will help you estimate the approximate savings you can make.

NATIONAL ANILINE DIVISION

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